1.0

2.8
2.5
3.2
2.2
3.6
4.0
2.0

1.1

1.8

1.25 1.4 1.6

MICROCOPY RESOLUTION TEST CHART

Report No. CG-N-1-80

LEVEL

THE STATE OF THE ART

BRIDGE PROTECTIVE

SYSTEMS AND DEVICE

AD A099790

DTIC
ELECTE
JUN 4 1981

S D

A

FINAL REPORT

1979

Superseded
AD-A0897(

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
United States Coast Guard

Office of Navigation

Washington, D.C. 20593

DTIC FILE COPY

FILE COPY

81 6 04

NOTICE

1. Report No. 19	2. Government Accession No.	3. Recipient's Catalog No.
CG-N-1-80	AD-A092 790	

4. Title and Subtitle		5. Report Date
The State of the Art, Bridge Protective Systems and Devices		1 October 1978
		6. Performing Organization Code
		USCG

7. Author's)	8. Performing Organization
K. N. Derucher, C. P. Heins	200-79-01-A

9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
University of Maryland	
Department of Civil Engineering	11. Contract or Grant No.
College Park, Maryland 20742	DOT-CG-71955-A

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
U. S. Coast Guard	Final Report
Office of Navigation	1979
G-NBR-1/14	14. Sponsoring Agency Code
Washington, D. C. 20593	G-NBR-1

15. Supplementary Notes

U. S. Coast Guard Technical Director: Ralph T. Mancill, Jr

16. Abstract

The report is intended as an aid in the design of bridge protective systems and devices.
The report includes: (1) factors considered in design and type of systems used; (2) advantages
and disadvantages of seven types of fendering systems; (3) material properties of fendering
systems; (4) design parameters; (5) hand calculation and computer application; and (6) conclusions
and recommendations of state-of-the-art study.

17. Key Words	18. Distribution Statement
Bridge	Document available through the
Fenders (Protection)	National Technical Information Service,
State of	Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	320	

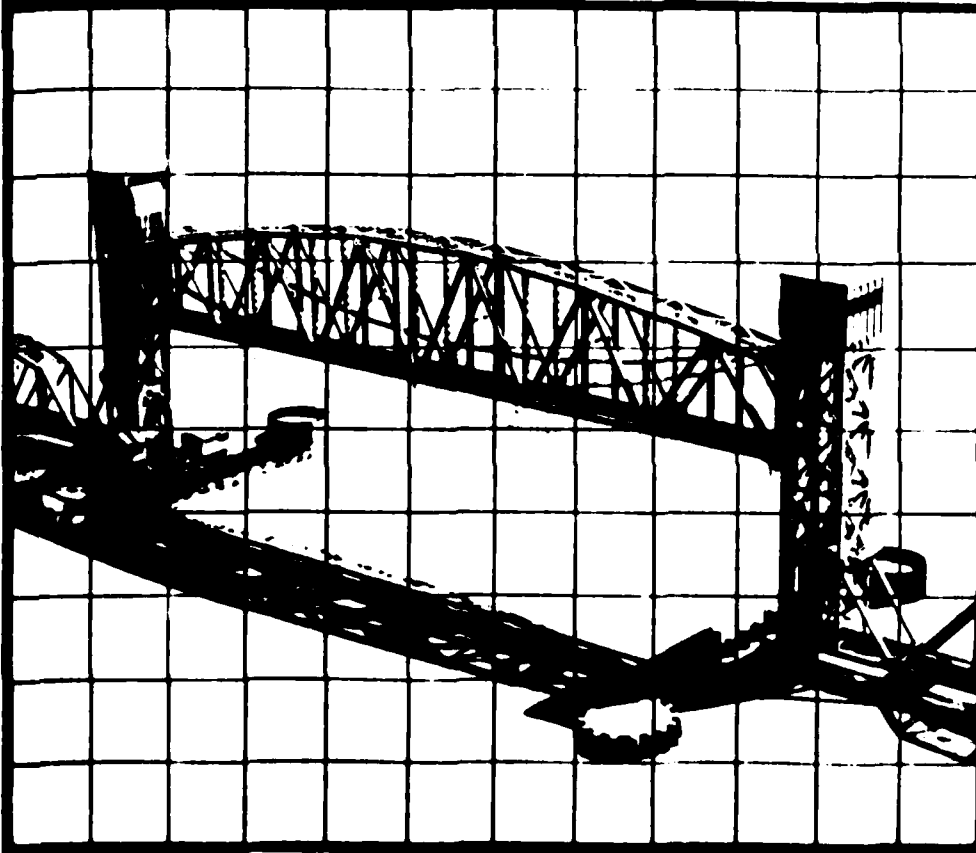Form DOT F 1700.7 (8-72)   Reproduction of completed page authorized

The State of the Art
Bridge Protective Systems and Devices

AUTHORS
Kenneth N. Derucher
Conrad P. Heins

EDITOR
Ralph T. Mancill, Jr.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PREFACE

Increasing demands are now being placed on our waterways and adjacent structures such as bridges, wharves, harbor piers, marinas, and lock entrances. These demands are attributable to the phenomenal growth in navigation module, whether it be a tanker, containership or barge tow. We have only to look back 15 years when the break bulk C-3 and the T-2 tanker were prominent on the seas. Let's look at the M.V. African Star, a break bulk C-3: 492 feet, 70 ft beam 16.7 kts and 12,000 dwt. Today the M.V. Sea-Land Finance: 946 feet, 105 ft beam, 33 kts, 27,000 dwt. Also, there was the T-2 tanker: 524 feet, 68 ft beam, 14.5 kts, 15,996 dwt. Contrast this with today's M.V. Texaco Sun: 745 feet, 102 ft beam, 17 kts, 53,453 dwt. Additionally, barges now moving on the Gulf Intracoastal Waterway measure up to 290 feet, each barge carrying 3000 dwt. Because of these increases in size and speed, the forces which can be delivered to structures adjacent to the waterway have substantially increased.

The increased number of collisions with bridges in recent years has focused more interest in the Coast Guard bridge replacement program. Designing a cost effective replacement bridge with a navigation prism, capable of meeting the present day needs of navigation, is easy to justify. These replacement bridges are highly cost effective because the replacement bridge provides for optimum productivity of navigation. In other words, vessels of economic size are able to utilize the waterway resource. However, the protection of bridge piers is another matter. They are not

unlike the car bumper which provide no utilitarian value of space or mobility to the passenger.

Conceptually, protection of the vessels and bridge piers is provided by a fender system adjacent to the navigation opening of the bridge, rather than the vessel. The dilemma which now exists is, simply, that vessels have grown in magnitude and disproportionately to the growth in size or capability of the bridge protection systems. To completely protect against maximum possible impact of collision, in some cases, now dictates placement of a mass in the waterway so heavy that its cost exceeds the cost of the bridge it protects. Such a mass, however, affords little or no protection to the vessel. These problems remain a concern of the bridge owner, the vessel operator, port authorities and the Coast Guard. It certainly follows that full utilization of existing technology and identification of these areas where research is needed will lead to better protective systems at lower cost.

Recognizing that a single source of reference, containing all existing technical data, methodology for selection of optimum fendering devices and recommended standards was urgently needed, the Coast Guard advertized for contract services for a State of the Art Study for Bridge Protective Systems and Devices on 25 February 1977. The applicability of this study to similar efforts in harbors was recognized by the American Association of Port Authorities, Committee IV. At Committee IV's suggestion the Coast Guard wrote in their contract to identify techniques that would be applicable to harbor structures, other than bridges. The research contract was awarded to the Department of Civil Engineering, University of Maryland on 15 July 1977.

During the interim of time that the State-of-the-Art Study was under-
way, I was able to share 10 years of experience in Coast Guard bridge
administration in return for an overview of specialized expertise of the
authors in their research and structural analysis. For many hours spent
accompanying Dr. Derucher and Dr. Heins in meeting with Port Directors,
harbor masters, pilots and consultant engineers, I am extremely grateful.
During these exchanges of information I was able to formulate several
basic assumptions which I would like to pass on to you: (1) a fender
system or as I prefer, an attenuation device, doesn't know whether it is
adjacent to a harbor pier or bridge pier, (2) a proper system will evolve
after using all known technology applied expertly to the precise situation
encountered, (3) elaborate and sometimes extensive mathematical computation
should be employed in each new set of circumstances, (4) more innovative
devices have recently been incorporated in the selection of harbor pier
protection than on bridge piers, (5) the key to success is not to increase
the mass or rigidity, but to increase the shock absorption or attenuation
qualities of the structure.

I view this undertaking as a useful compilation of information
presently available, but more importantly a plateau from which we can
now plunge into the overdue, long sought improvement in the present
state-of-the-art. It is hoped that this book will serve as useful
reference to the harbor master, the port engineer, the consultant engineer,
the bridge owner and the Coast Guard officer engaged in bridge matters. I
look forward to an eventual up-date of existing standards calling for
better design calculations and innovated design concepts. I feel the most
useful contributions of this effort is in the area of computer analysis

which will be used by the Coast Guard and hopefully to a greater degree by the consultant engineer in his effort to optimize the design of a specific fender system. Of course, the computer is only an aid and will not supplant the consultant's years of experience, innovated design concepts, realization of cost savings in the installation and maintenance of a particular system foremost in the mind of the Port Director and bridge owner.

Ralph T. Mancill, Jr.
Chief, Bridge Modification Branch
U.S. Coast Guard Headquarters
EDITOR

CHAPTER I

INTRODUCTION

GENERAL

Tankers, bulk carriers, cargo vessels and barges are being built increasingly larger in recent years. They require more room to maneuver and supply greater cargo capacities than ever before. This places increasing demands on waterways and adjacent structures such as bridges, docks, harbors, piers, marinas, lock and port entrances.

Coast Guard casualty statistics show that vessel collisions with fixed objects, such as bridges, more than doubled between 1966 and 1975 as larger and greater numbers of vessels used the nation's waterways. One Coast Guard study reveals that during the period FY71 and FY75, $23,153,000 in damage and fourteen fatalities were encountered. Obviously, such statistics indicate that a need exists to assure that proper design practices are used for fendering system installation. This need was recognized by the Bridge Division, U.S. Coast Guard, which is charged with the responsibility to provide for the economic efficiency and safety of marine transportation under bridges spanning the navigable waters of the United States. They have initiated a research contract with the Department of Civil Engineering, University of Maryland to conduct a study of the State-of-the-Art of Bridge Fendering Systems."

FACTORS CONSIDERED IN THE DESIGN

The function of bridge fendering systems are to protect bridge elements against damage from waterborne traffic. There are many factors to be considered in the design of fendering systems including the size, contours, speed, and direction of approach of the ship using the facility; the wind and tidal current conditions expected during the ship's maneuvers and while tied up to the berth; and the rigidity and energy-absorbing characteristics of the fendering system and ship, and finally the subgrade soil condition. The final design selected for the fender system will generally evolve after making arbitrary limitations to the values of some of these factors and after reviewing the relative cost of initial construction of the fendering system versus the cost of fender maintenance and of ship repair. In other words, it will become necessary to decide upon the most severe docking or approach conditions to protect against and design accordingly; hence, any situtation which imposes conditions which are more critical than the established maximum would be considered in the realm of accidents and probably result in damage to the dock, fendering system (whether used for dock or approach conditions) or the ship.

TYPES OF FENDERING SYSTEMS

As a result of the factors considered in the design, many fendering systems have been designed and/or analyzed. These systems are of wide variety and material which vary considerably in design, fabrication, and cost. As a result of the literature search, basically seven types of fendering systems are in existence. These seven systems are as follows:

1. Floating Fender or Camels

2. Standard Pile-Fender System

    a. Timber-Pile

    b. Hung Timber

    c. Steel Pile

    d. Concrete Pile

3. Retractable Fender System

4. Rubber Fender System

    a. Rubber in Compression (Seike)

    b. Rubber in Shear (Raykin)

    c. Lord Flexible

    d. Rubber in Tension

    e. Pneumatic

5. Gravity Type Fender System

6. Hydraulic and Hydraulic-Pneumatic Fender System

    a. "Dashpor" Hydraulic

    b. Hydraulic-Pneumatic Floating Fender

7. Spring Type Fender System

As indicated, the above seven (7) fendering systems were found to be in existence throughout the world by a comprehensive library and computer literature search. These systems will be explained in subsequent chapters as to advantages, disadvantages, design parameters, materials of construction and design procedures (hand and computer oriented).

CHAPTER II

TYPES OF FENDERING SYSTEMS

This chapter deals with the various types of fendering systems as mentioned in Chapter I. The uses, advantages, and disadvantages of each type will be discussed. Although the authors discuss the fendering systems in general terms, it should be remembered that fenders are applicable to both the docking and mooring problem as well as bridge protection.

FLOATING FENDER OR CAMEL

The floating fender or camel is the simplest type of fendering system employed. This is often used in combination with other types of fendering to provide a large contact area and thereby increase the efficiency of the fendering system while decreasing the load concentration at any one point on the fender. They may be used as rubbing surfaces to protect the ship's hull from damage by the dock structure during berthing procedures or from damage by the action of other ships while moored. Traditionally, the camel has consisted of treated logs of Douglas fir, Southern pine, White oak, Red oak, or any wood with relatively high fiber hardness and high bending strength. Greenheart and other exotic woods have natural marine borer resistance but are heavier than water, making their use as camels impractical in most cases. The treated timber is hung on chains in single units, bundled groups, or dapped and bolted heavy box sections. The high weight, strength, and stiffness of the box sections have limited their use to busy Navy installations where they have performed satisfactorily in most instances. Energy absorption occurs as a result of crushing of the timber fibers and bending of

the camel groups. Loss of strength may occur where the timber has been splintered due to faulty construction practices or high energy considerations or where degradation of the wood has occurred due to marine borer attack or rotting. Though the camel has been used for years as a component of many fendering systems, it may result in severe damage to the ship's hull and fender, dock or bridge structure as a result of concentrated loadings along the length of the camel during high energy impacts. Projecting hardware on the camel or fendering structure may result in tears or punctures to the ship's hull.

The latest development in floating fenders came in 1967 in which the Hi-Dro Cushion camel (Fig. 1) was constructed and tested at Treasure Island Naval Station in San Francisco, California. The Hi-Dro Chsion camel consists of eighty-four, three foot water filled cells, grouped into four clusters, sandwiched between two timber rubbing faces and held in place by cables. The water filled cylinders maintain constant pressure during compression upon impact by forcing water out through small orifices in the tops of the cylinders. The compression of the cylinders and the resulting hydraulic action, as well as the bending of the timber faces, crushing of the timber fibers, and movement of the water between the cell clusters, result in higher energy absorption than that of the traditional camel. In addition, the Hi-Dro Cushion can adjust to varying ship displacement, approach velocities, and environmental factors.

STANDARD PILE FENDER SYSTEM

The timber-pile (Fig. 2) system employs piles driven along a wharf, face bottom. Pile tops may be unsupported laterally or supported at various degrees of fixity by means of whalers and chocks. Single or multiple row whalers may be used, depending on pile length and tidal variation. Impact
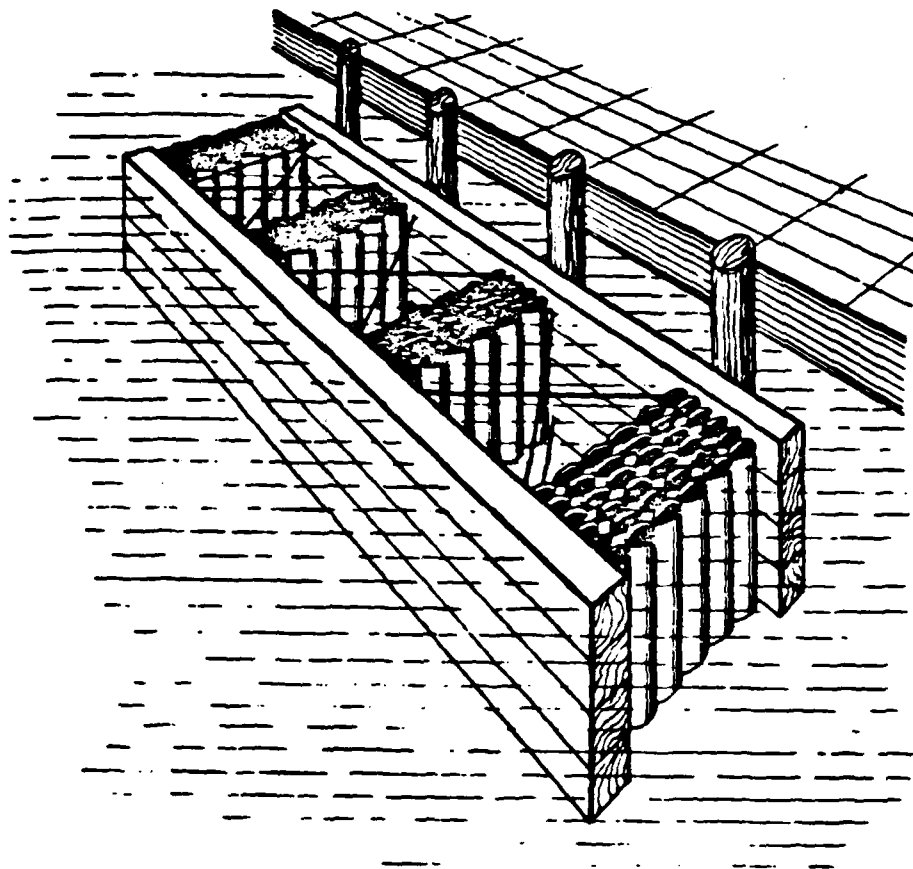
FIG. 1: Hi-Dro Cushion Camel (Courtesy of Rich Enterprises)

6

PLAN (without lower wale)

PLAN (with lower wale)

SECTION
(a) WITHOUT LOWER WALE

SECTION
(b) WITH LOWER WALE
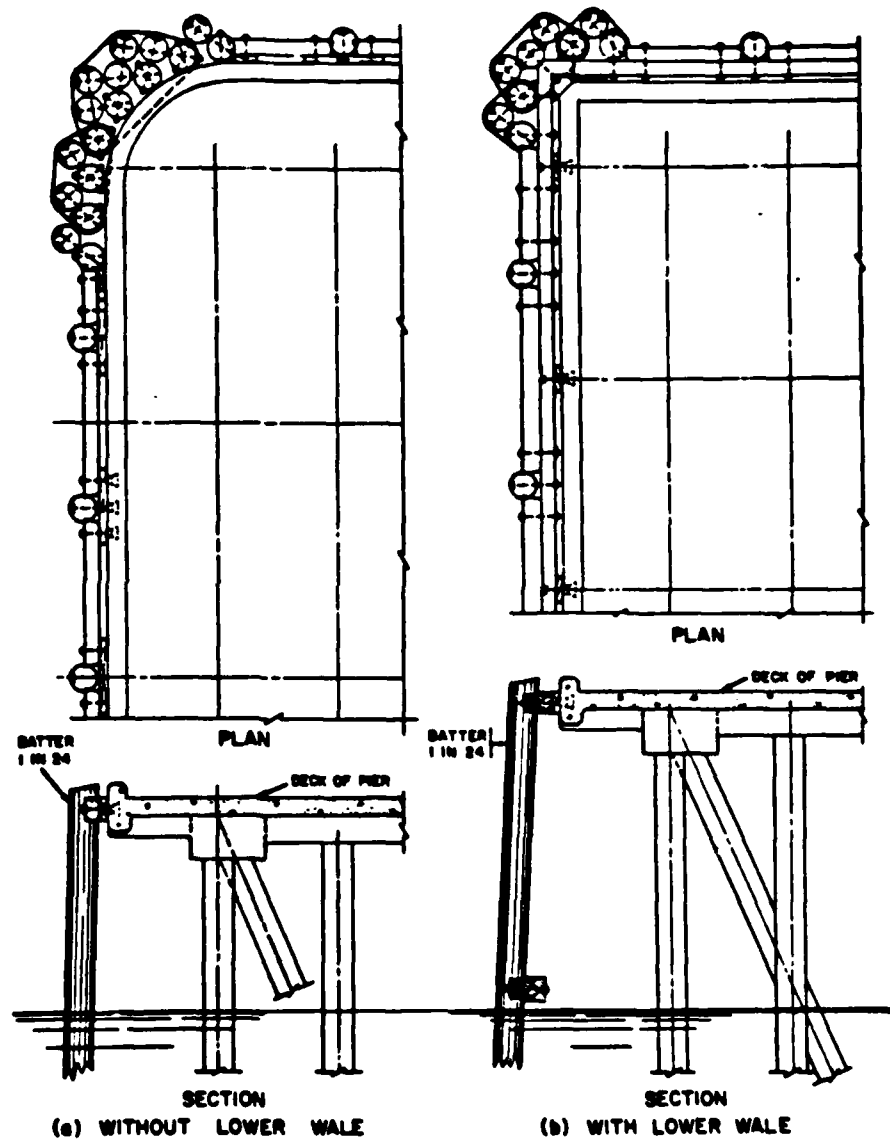
FIG. 2: Timber Fender Piles (Courtesy of U.S. Navy)

7

energy upon a timber fender pile is absorbed by deflection and the limited compression of the pile. Timber piles are abundant and have a low initial cost. They are susceptible to mechanical damage and biological deterioration. Once this happens, the energy-absorption capacity declines and a high maintenance or repair cost results. Timber piling can be observed in satisfactory service in most marinas where smaller recreational vessels are berthed and moored. For large vessels and less sheltered waterways, steel, concrete, or composite sections have gained wide acceptance.

The hung timber system (Fig. 3) consists of timber members fastened rigidly to the face of the dock. A contact frame is formed which distributes impact loads, but its energy-absorption capacity is limited and it is unsuitable for locations with significant tide and current effects. Whalers should be provided along the length of the rubbing strip with additional whalers provided near mean low and mean high water. The hung timber system has a low initial cost and is a less bio-deterioration hazard than the standard timber pile.

Since World War II various materials have been used in conjunction with the hung timber fenders. Cylindrical and rectangular rubber pieces, hydraulic units, and steel springs have been inserted behind the timber framework in order to improve the energy absorption characteristics of the hung fender.

Steel fender piles are occasionally used in water depths greater than forty feet, or for locations where very high strength is required and a difficult seafloor condition results. Its main disadvantages are high cost and its vulnerability to corrosion.

Regular, reinforced concrete piles are not satisfactory because of their limited internal strain-energy capacity and the steel reinforcement may corrode due to concrete cracking. Prestressed concrete piles with rubber buffers at deck level have been used. In this case, the rubber units are the principal

8

PLAN

STEEL SHEET PILING

CONCRETE CAP AND CURB

BOLLARD FOUNDATION

€ OF CELL

PLAN

PLAN

DECK OF PIER

MLW

SECTION
(a)FILLED CELLULAR PIER

DECK OF PIER

MLW

SECTION
(b) OPEN-TYPE PIER
(SEE ALSO FIGURE 1-17)
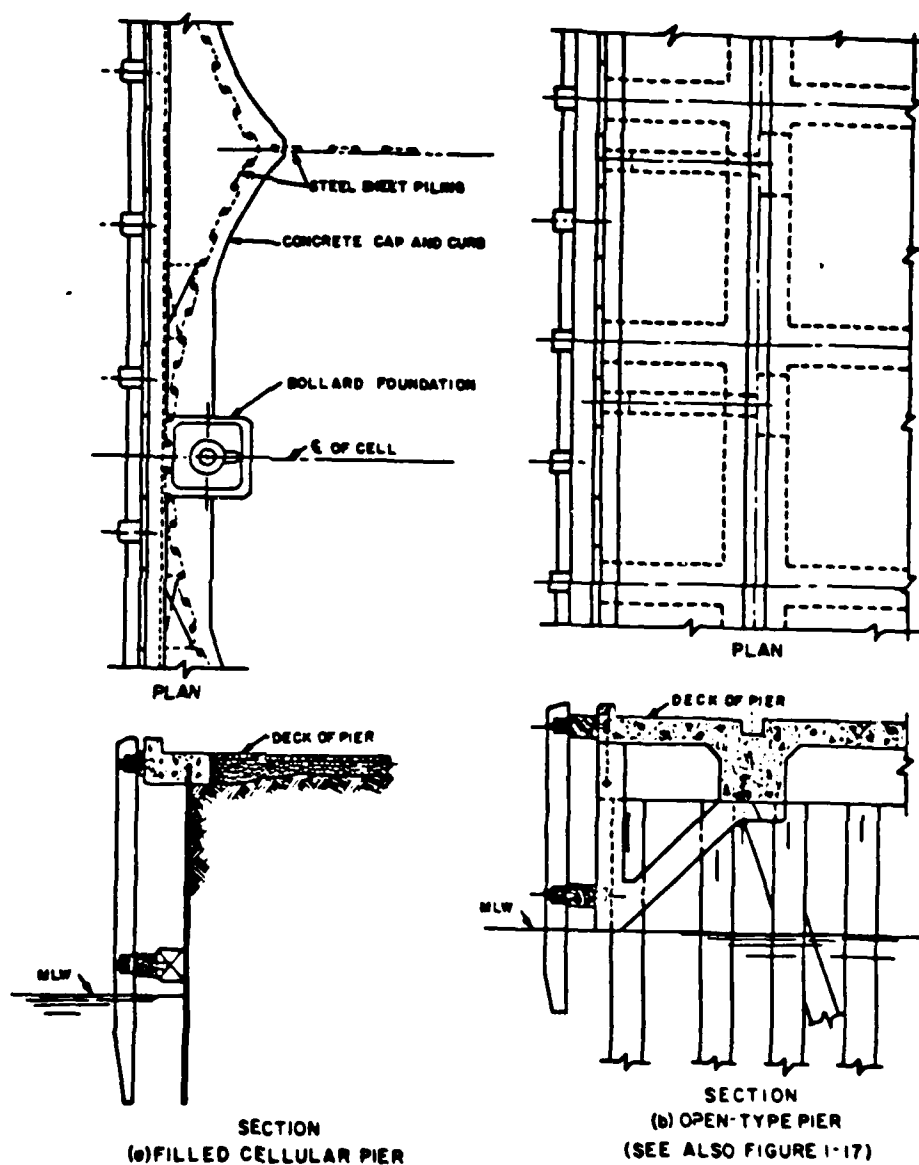
FIG. 3: Hung Timber Fenders (Courtesy of U.S. Navy)

9

energy-absorbing media; and not the piles. This system is very resistant to natural and biological deterioration.

RETRACTABLE FENDER SYSTEM

Retractable fenders generally consist of a timber or steel framework with timber facing members supported on open pins or slotted brackets (Fig. 4) fastened to the pier or dock structure. Energy absorption occurs as a result of the vertical displacement of the fender, friction in the brackets, and bending and crushing of the timber fibers. When berthing maneuvers result in an impact force greater than the resultant of the weight of the fender in the direction of the brackets and the friction of the brackets, the fender begins to move upward and backward toward the dock face. As this motion occurs, more timber facing strips are brought into contact with the ship's hull increasing the resistance of the fender to further movement. Impact energies are rarely of sufficient magnitude to push the fender to the dock face, but, should this occur, additional fendering is provided by the deformation of the timber facings and then the underlying framework.

Design considerations must include the effective weight of the fendering system which is directly affected by tidal variations, maximum retracting distance, angle of inclinations of the brackets, and the sufficient number of brackets. Damage to the supporting brackets can render the fender inoperative although replacement of the timber facing strips does not adversely affect energy absorption or present difficulties for repair. Provisions for glancing blows may include allowance of a slight amount of slip in the brackets. The fender will then bear upon the bracket wall of each fendering section which comes in contact with the vessel.

Recent innovations in the area of retractable fenders include the use of steel framework with rubber tires or cylindrical fenders positioned around

10
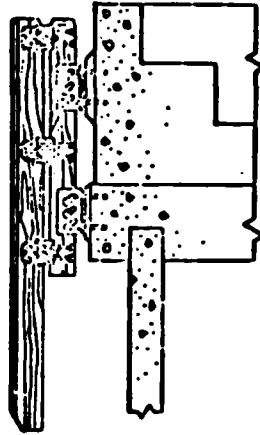
(a) Slotted supporting brackets

(b) Open pin supporting brackets

FIG. 4: Retractable Fender Brackets (Courtesy of U.S. Navy)

the vertical axis allowing free rotation about the vertical axis. This system incorporated counterweights to counteract the negative moment of portions of the frame loaded seaward from the bearing piles. The rubber tires eliminate many of the concerns regarding glancing blows by allowing free rotation, decreasing the severity of the reaction force which would result from timber sections, and reduce wear and maintenance of contact members.

RUBBER FENDER SYSTEMS

The rubber fender systems occur in five types as outlined earlier. Rubber in compression (Seike) consists of a series of rubber cylindrical or rectangular tubes installed behind standard fender piles or behind hung-type fenders. Energy absorption occurs as a result of the deflection of the fender and/or the internal stress-strain characteristics of the rubber material. When bolted directly to the face of the pier, care must be taken to insure that all bolts are recessed and firmly anchored in the dock structure (Fig. 5). In design, a proper bearing timber-frame is required for transmission of impact forces from ship to pier.

Cylindrical and rectangular units can be used interchangeably in most instances (Fig. 6). When mounted on the flat face of a pier, they may be bolted directly to the face of the dock, draped, hung vertically (Figs. 7 and 9), or layered using one or more of these methods (Fig. 8). On curved structures, draping is not possible and the fenders must be bolted to the face of the pier or hung vertically. Draped fenders require a solid dock face of at least six feet to insure at least a three foot depth of contact between the fender and the ship's hull. This makes pre-curved sections a necessity. All connections should be recessed so that they do not protrude beyond the face of the dock. The low point of each fender should be fitted with a drain hole.

12

FIG. 5: Rectangular Rubber Fender (Courtesy of Goodyear)
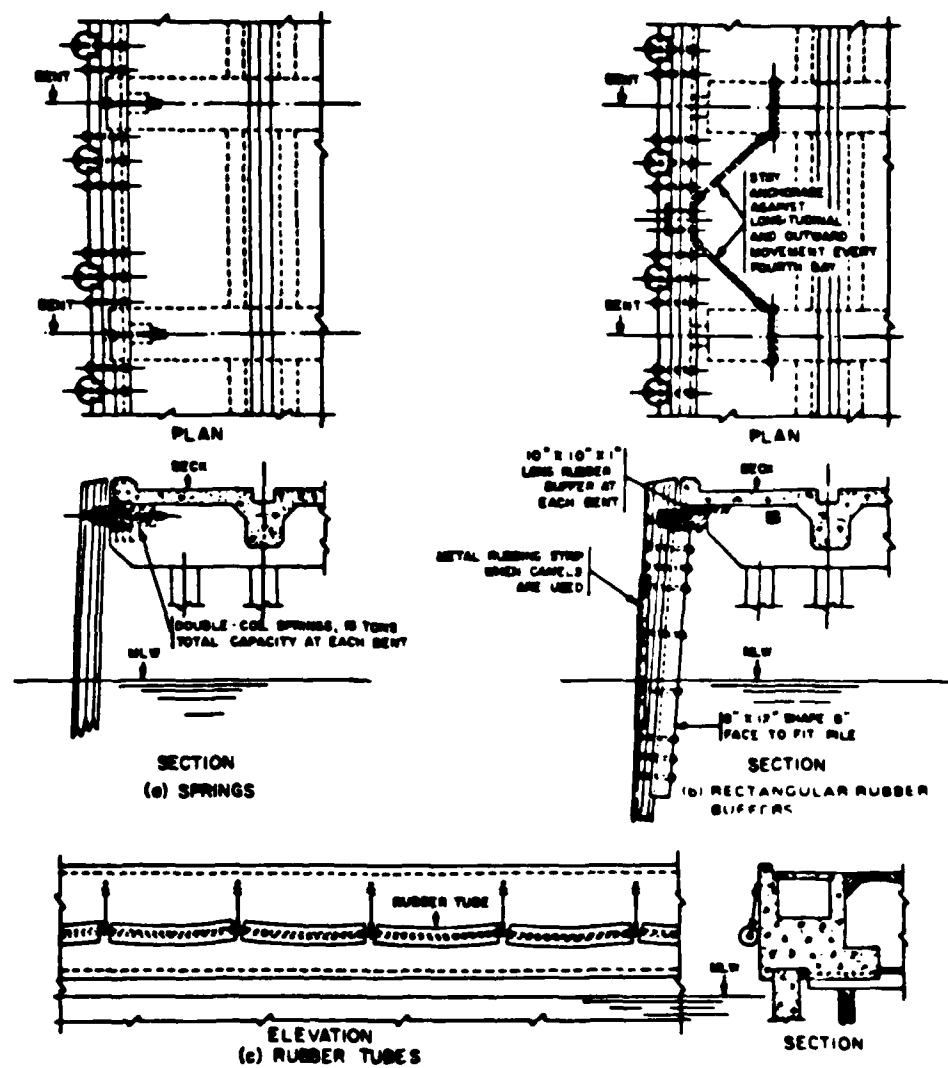
FIG. 6: Mounting of Rubber Fenders (Courtesy of U.S. Navy)
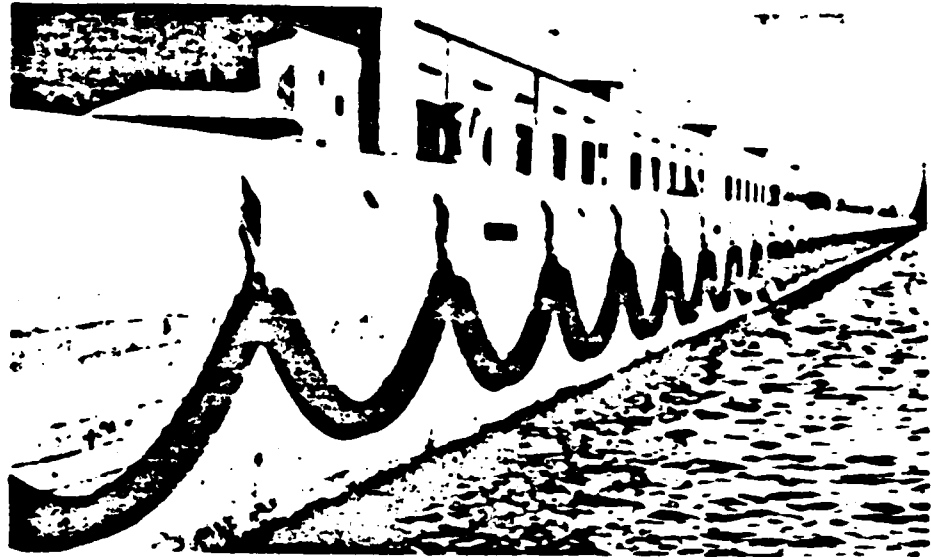
a. Cylindrical

b. Trapezoidal

FIG. 7: Rubber Fenders (Courtesy of Goodyear)

15
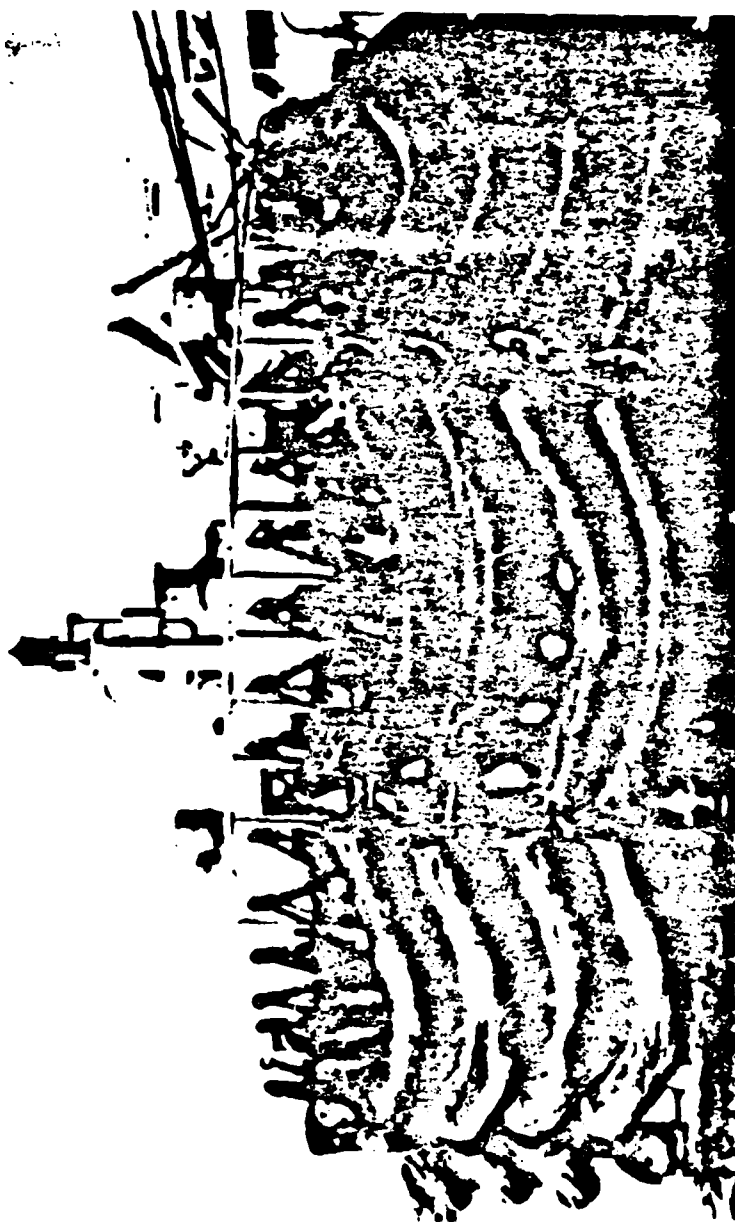
FIG. 8: Layered Rubber Fenders (Courtesy of Goodyear)
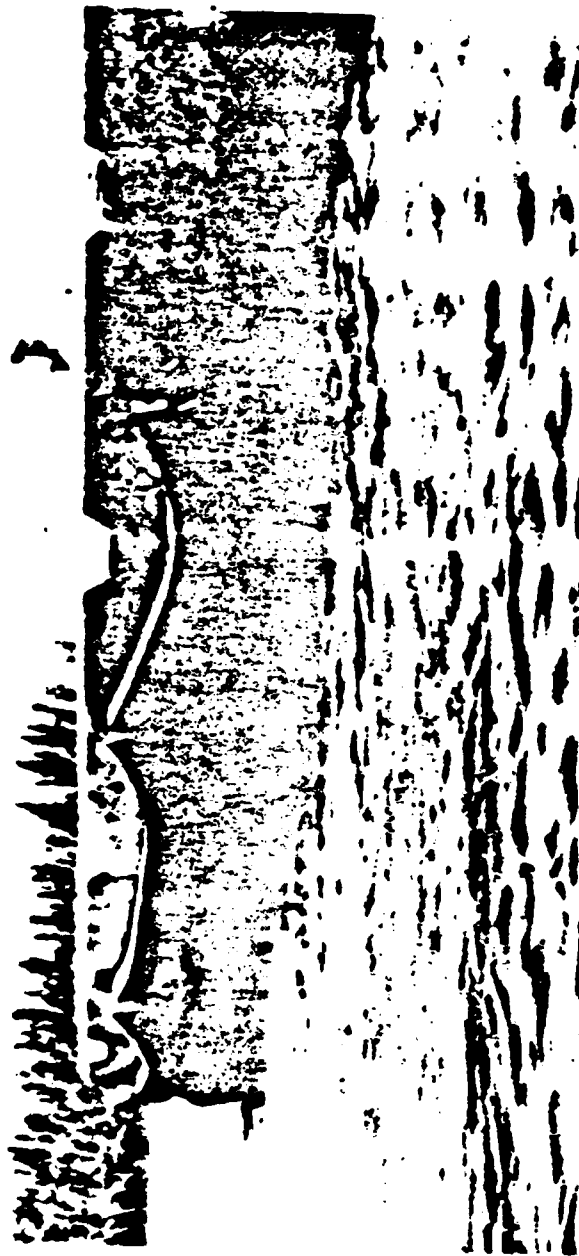
FIG. 9: Draped Rectangular Rubber Fenders (Courtesy of Uniroyal)

17

When rubber fenders are applied to the dock face in any of the above manners, certain problems arise due to the contact of the vessel and rubber fender. The rubbing action of the ship's hull against the fender may damage the fender if unevenness exists along the hull due to rivets, butt joints, or any number of slightly protruding elements.

Energy absorption capacity of such a system can be varied by using the tubes in single or double layers, or by varying tube sizes. The energy absorption of a cylindrical tube is nearly directly proportional to the ship's force until the deflection equals approximately one-half the external diameter; after that, the force increases much more rapidly than the absorption of energy.

Another method of utilizing rubber in compression is to mount the rubber behind timber rubbing strips thereby eliminating the contact of the rubber against the ship and all of the ensuing difficulties (Figs. 10 and 11). In this manner, additional energy absorption is provided by the bending and crushing of the timber fibers. Rubber fenders may be positioned with the bore parallel or perpendicular to the dock face. When positioned perpendicular to the dock so that the sections are axially end-loaded (Fig. 12), the energy absorption and reaction force curves are very nearly linear. When positioned parallel to the dock so that the sections are loaded perpendicular to the bore of the fender, there is a disproportionate increase in both the energy and force for a given deflection (Fig. 13). Therefore, using either the cylindrical or rectangular fenders in axial compression allows design over a larger range of deflections than using either in radial compression.

Still, another type of rubber fender used in compression is the trapezoidal fender of which two types exist: the internal bottom mounting plate (Fig. 14a) and the external bottom mounting plate (Fig. 14b). These fenders
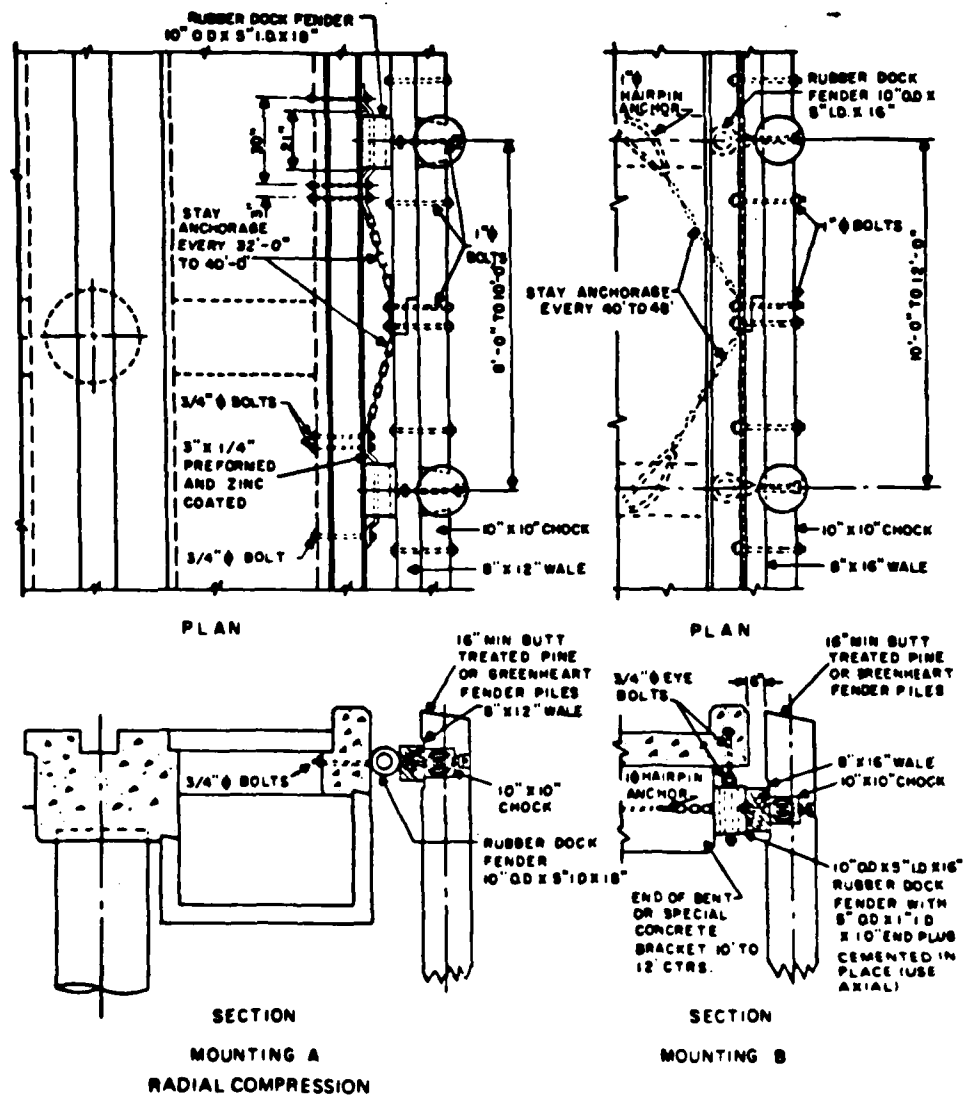
FIG. 10: Rubber Fenders Mounted Behind Hung Timber Fenders
(Courtesy of Little)

PLAN

PLAN

SECTION
MOUNTING A
RADIAL COMPRESSION

SECTION
MOUNTING B
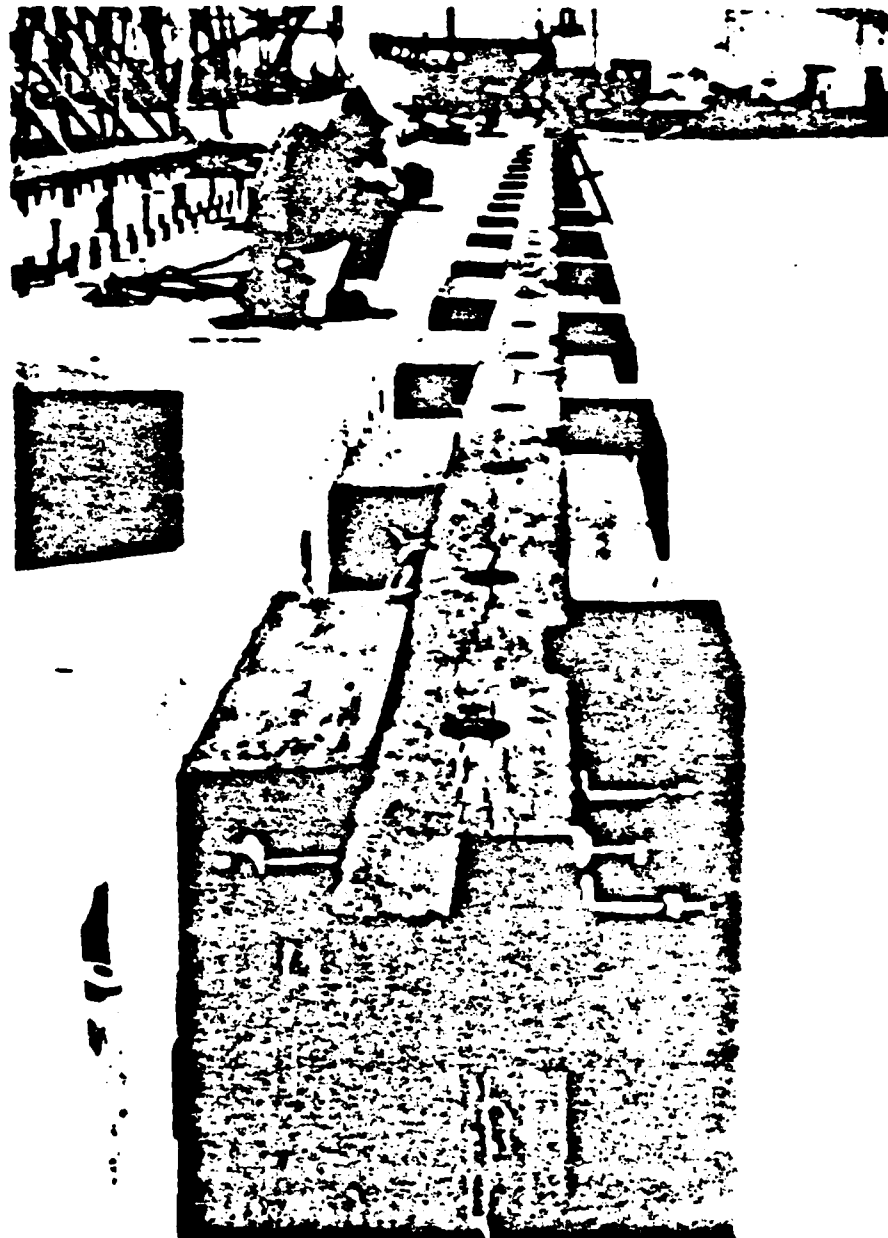
FIG. 11: Rubber Fenders Mounted Between Wood Assemblies
(Courtesy of Uniroyal)

20
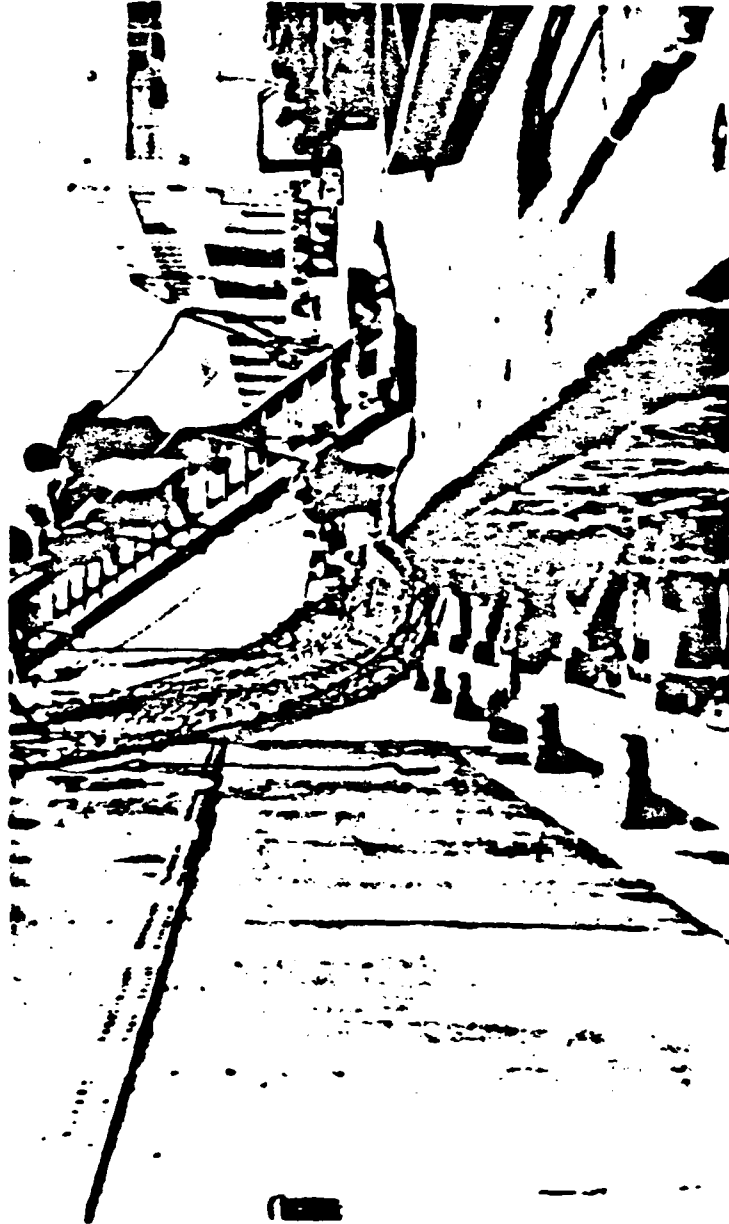
FIG. 12: Axially Mounted Rubber Fenders (Courtesy of Goodyear)

21

FIG. 13: Side Loaded Rubber Fender Assemblies (Courtesy of Uniroyal)

a. Vertically Mounted External Plate

b. Horizontally Mounted Internal Plate

FIG. 14: Trapezoidal Rubber Fenders (Courtesy of Goodyear)

may be bolted either horizontally or vertically to the face of a dock or they may be applied behind timber rubbing strips. When mounted between the timber facing and the dock, they may be used singly or may be bolted together to form what resembles a large rubber "X" either with or without a top or bottom (Fig. 15).

Rubber funders in compression may also be applied directly to the vessels (Fig. 16).

The Raykin fender (Fig. 17) is the most commonly used rubber in shear system. The Raykin consists of a series of rubber pads bonded between steel plates to form a series of "sandwiches" mounted firmly as buffers between a pile-fender system and pier. Two types of mounting units are available, which are capable of absorbing 100 percent of the energy. The only problem with the rubber in shear fenders is that they tend to be too stiff for small vessels and the steel plates have a tendency to corrode. Therefore, it follows that they have a high energy absorbing capacity for larger ships.

Solid cylinders and rectangular rubber members have been used as shear fenders. By attaching the rubber section to the underside of the dock and to a horizontal piece of timber or steel to which timber rubbing strips are attached, the rubber is put into direct shear by any impact load (Figs. 18 and 19). As with the Raykin fender, this system is best suited for a large, uniform ship size and is not soft enough for smaller ships.

The Lord flexible fender (Fig. 20) consists of an arch-shaped rubber block bonded between two end steel plates. Under axial loading, the Lord fender buckles in much the same way that a column will buckle if the slenderness ratio becomes large enough to cause instability. It can be installed on open or bulkhead type piers and on dolphins, or incorporated with standard piles as the hung system. Impact energy is absorbed by bending and compression of the arch-shaped rubber column. With the Lord flexible fender, possible destruction of the bond between the steel plates and rubber may result.

24
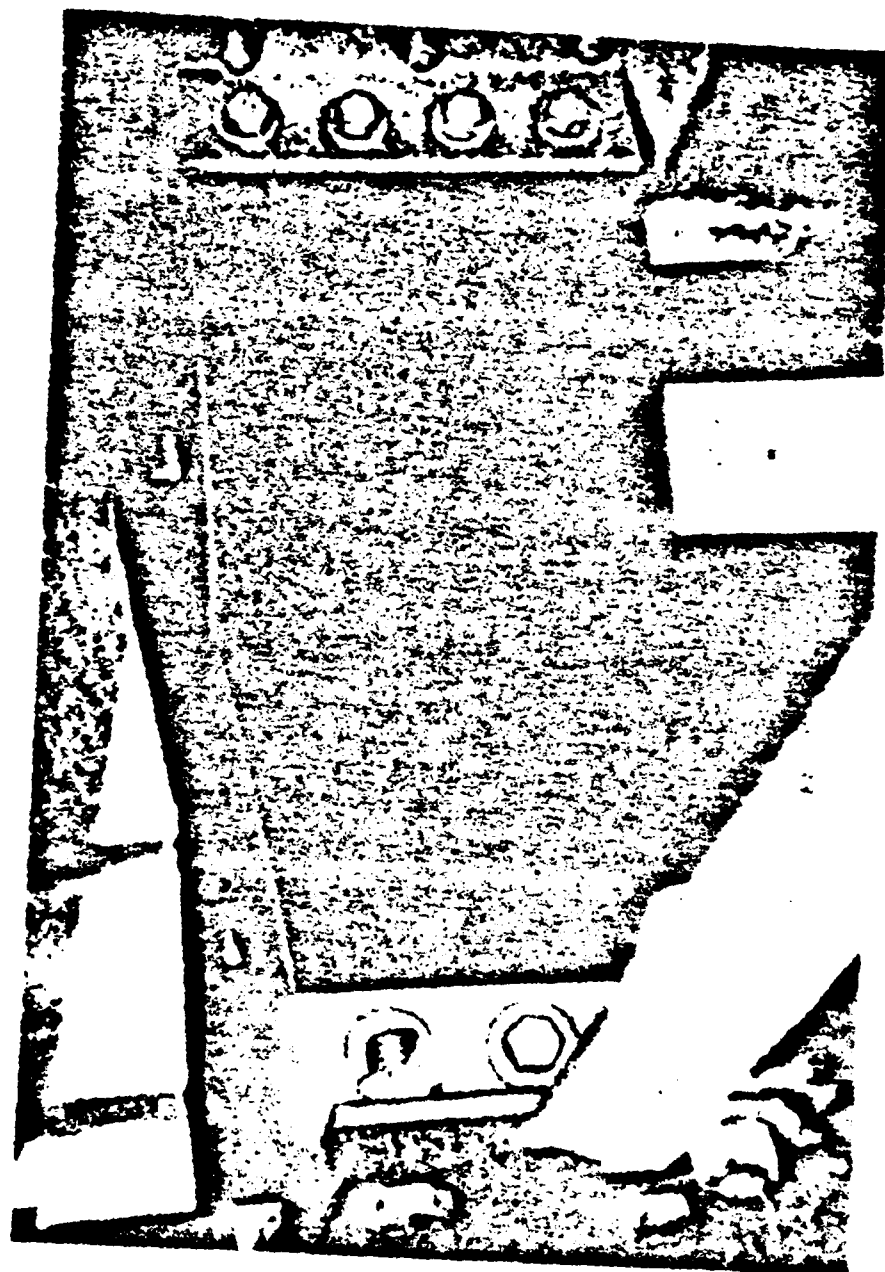
FIG. 15: Double Mounted Trapezoidal Rubber Fenders (Courtesy of Uniroyal)
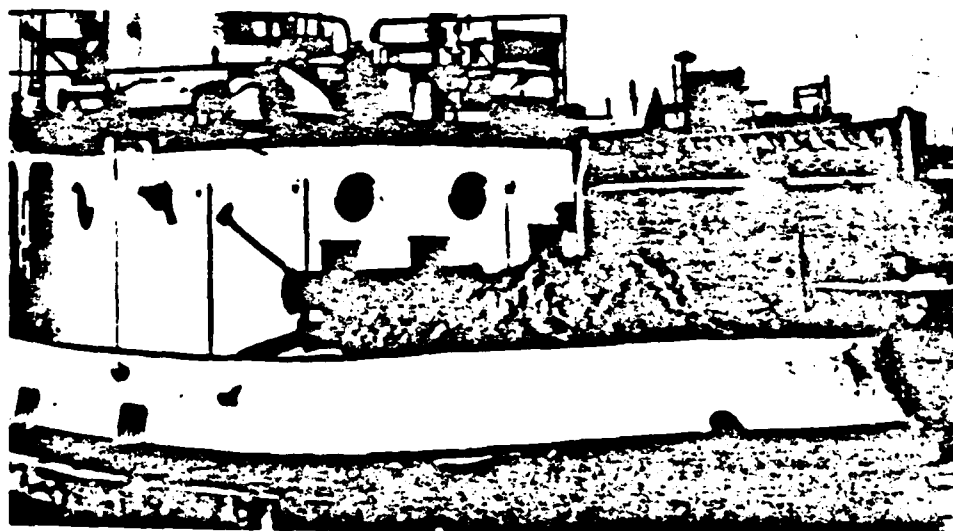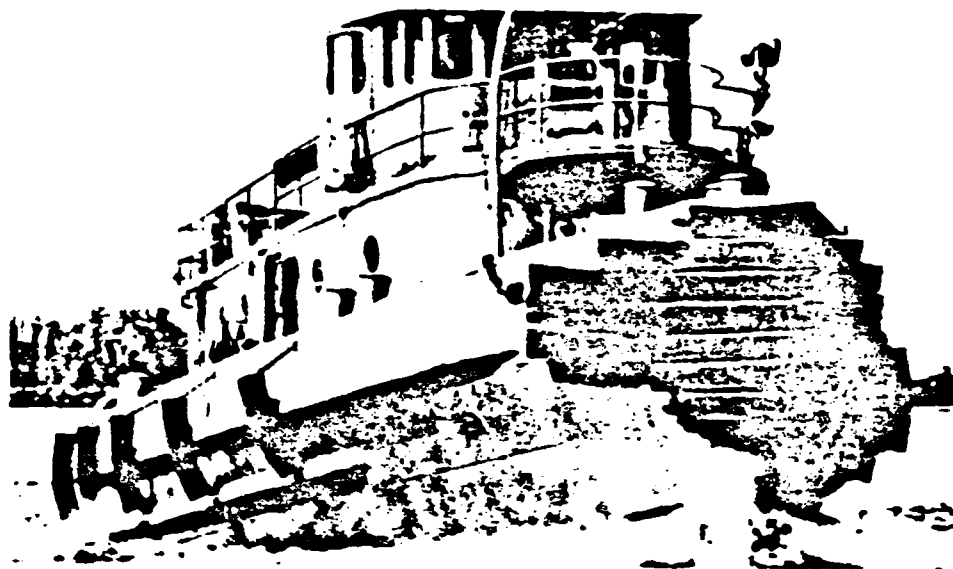
FIG. 16: Rubber Fenders Aboard Ship (Courtesy of Goodyear)

ELEVATION   SIDE VIEW

Labels in figure: BEARING PLATE, STEEL PLATES, RUBBER SANDWICHES, STOPS, MOUNTING PLATE
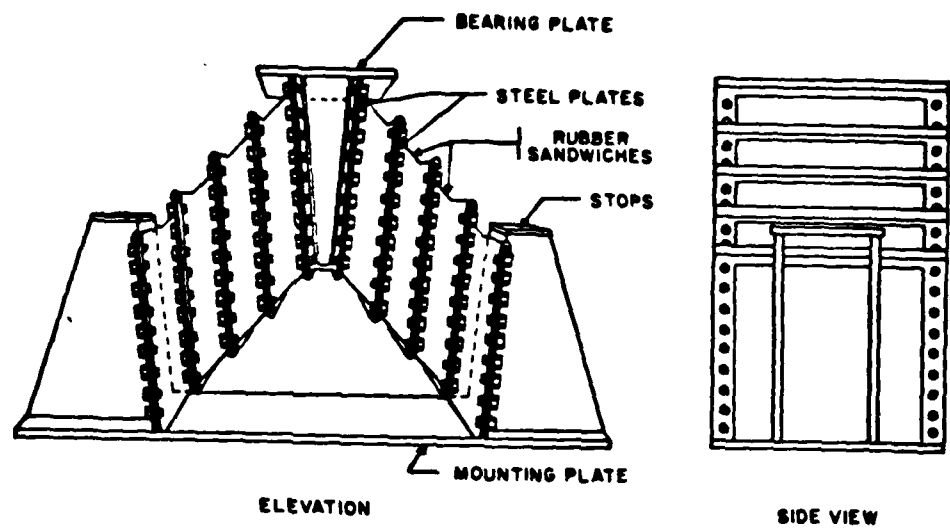
FIG. 17: Raykin Fender (Courtesy of U.S. Navy)
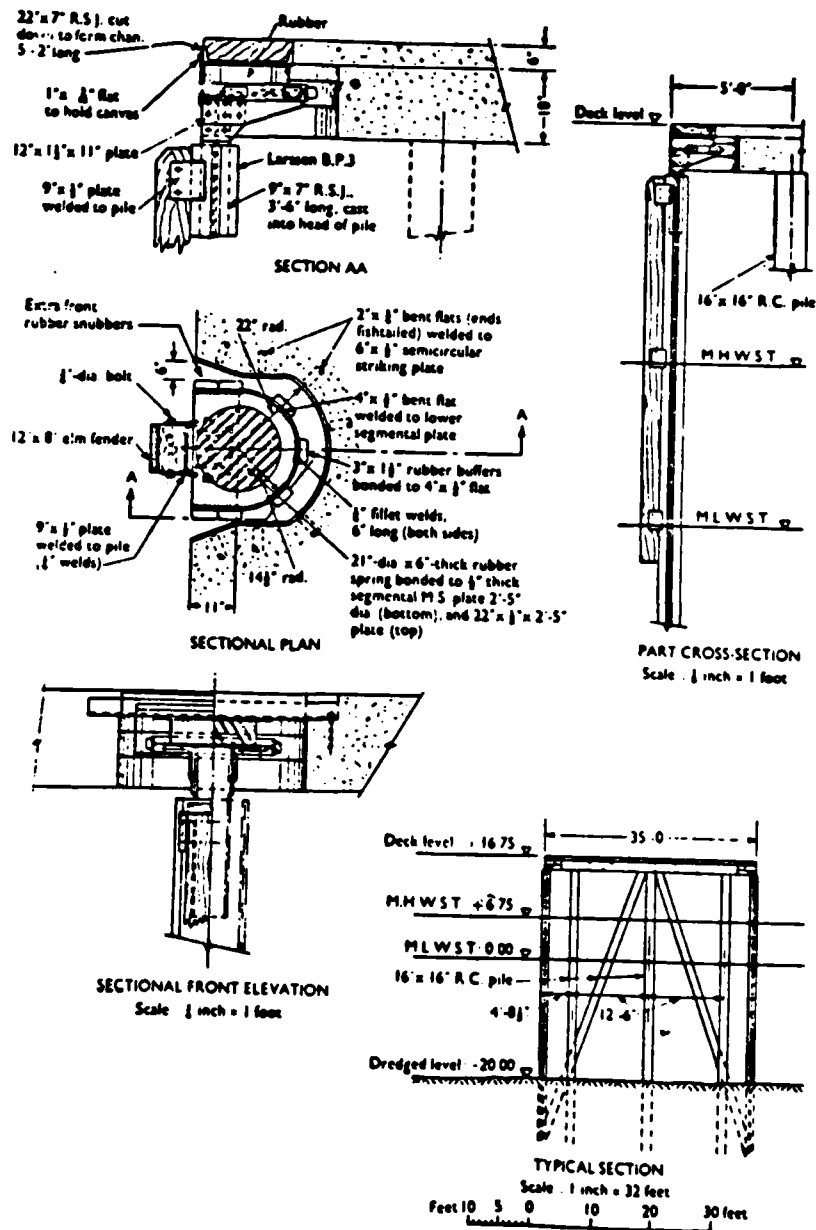
FIG. 18: Rubber Fender in Shear (Courtesy of Little)

28
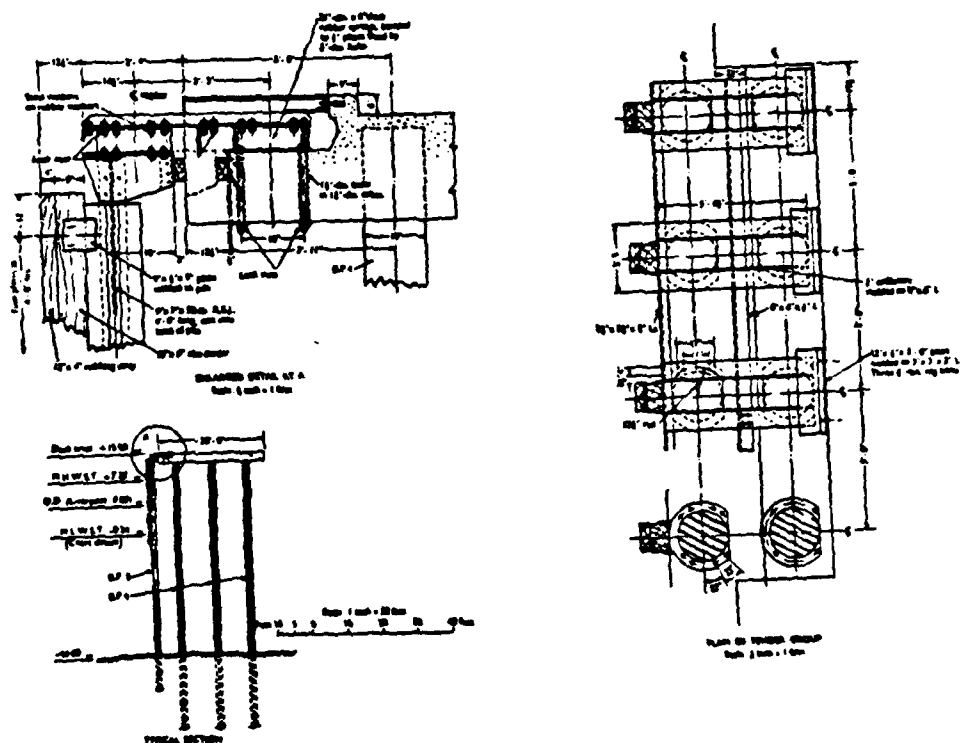
FIG. 19: Rubber Fender in Shear Mounting (Courtesy of Little)

Plan View

Plan View

Lord fender

auxiliary
rubber fender

timber
rubbing strips

Lord fender

Lord fender

Lord fender

Lord fender
after buckling

Lord fender
after buckling

auxiliary
rubber fender

steel fender pile

Profile View

Profile View
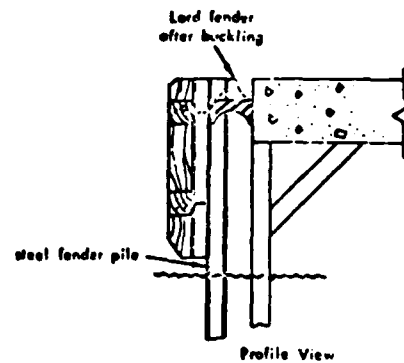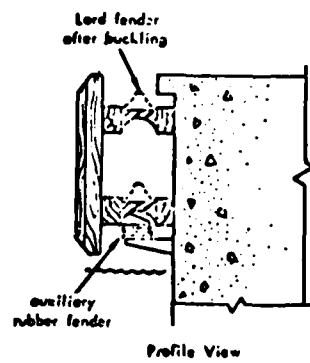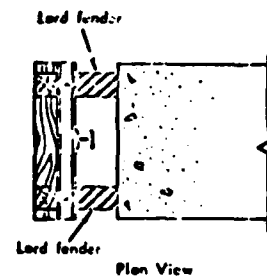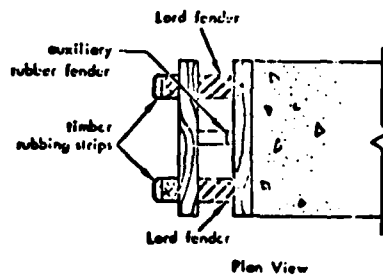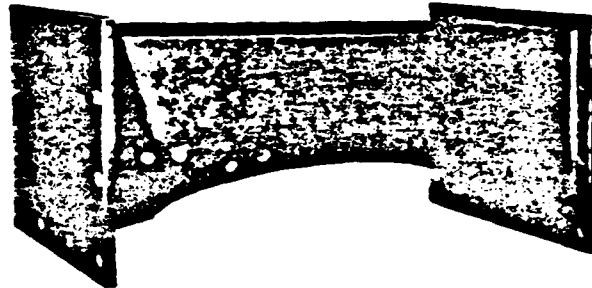
(a) Hung-type Lord fender system

(b) Fixed-pile Lord fender system

FIG. 20: Lord Flexible Fender (Courtesy Lord Co. and U.S. Navy)

Rubber in tension fenders consists of a combination of rubber and steel fabricated in a cone-shaped, compact bumper form, molded into a specially cast steel frame, and bonded to the steel. It absorbs energy by torsion, compression, shear, and tension. Their main disadvantage is possible destruction of the bond between steel castings and the rubber.

The final category of rubber fendering systems is the pneumatic fenders. These are pressurized, airtight rubber devices designed to absorb energy by compression of air inside a rubber envelope (Fig. 21). Pneumatic fenders have recently been applied to fixed dock-fender systems (Fig. 22) and are feasible for use as ship fenders or shock absorbers on floating fender systems. Two pressure ranges are used in the pneumatic fenders, approximately one psi and seven psi. A proven fender of this type is the pneumatic tire wheel fender which consists of pneumatic tires and wheels capable of rotating freely around a fixed or floating axis. The fixed unit is designed for incorporation in concrete bulkheads. The floating unit may consist of two to five tires. Energy-absorption capacity and resistance load depends on the size and number of tires used and on initial air pressure when inflated.

Pneumatic fenders can be hung by cable or chains through the metal end rings which are located at each end or they may be encased in a net and hung at various points along the fender length (Fig. 23). When used on a dock or pier, the abrasion resulting from berthing and mooring can be prevented by the use of tires fastened to the pneumatics by a network of rope or cable. The range of sizes available allows for design of an adequate fendering system even when space is critical.

A recent development in the pneumatic field is the use of foam filled fenders (Fig. 24). During accidental collisions, there is a slight chance that the pneumatic fenders may be overloaded and release air through a release valve or through a puncture. In this event the fender becomes completely

31
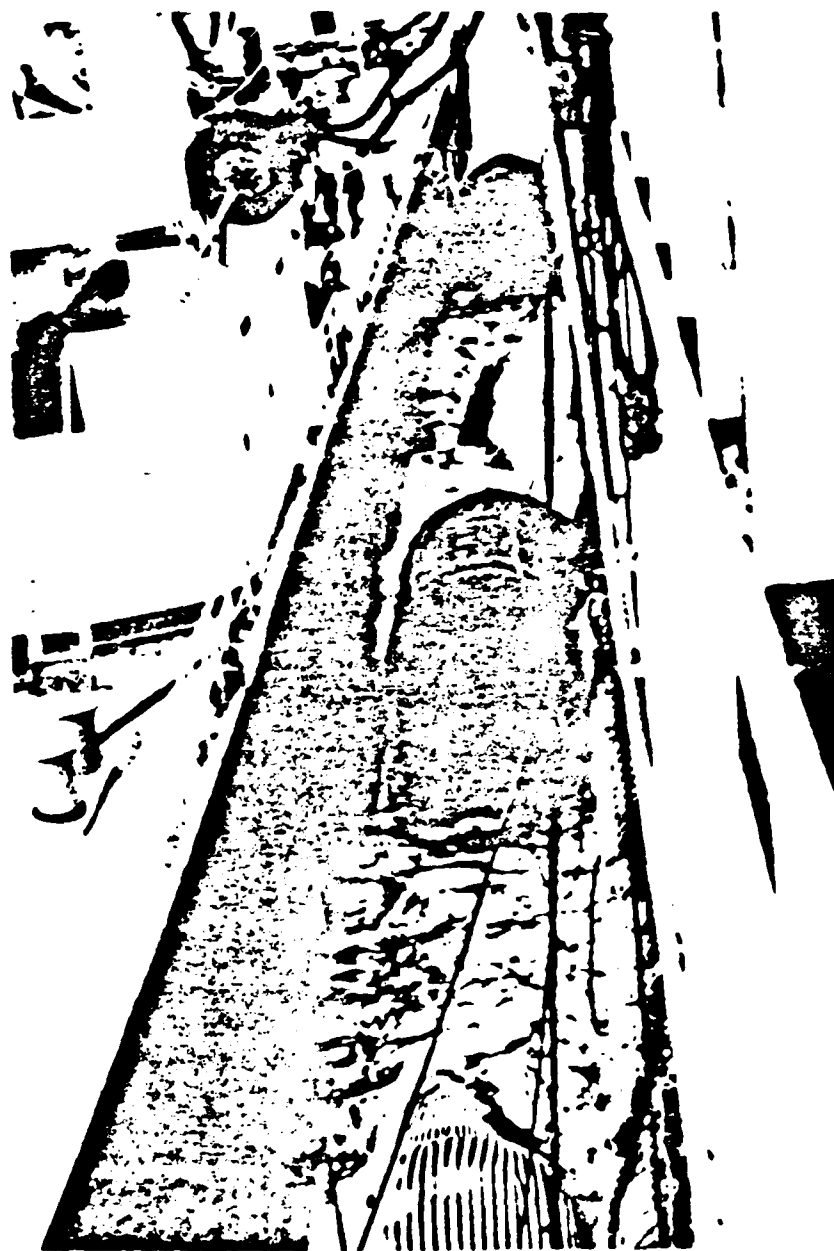
FIG. 21: Pneumatic Fenders in Whaling (Courtesy of Yokohama)
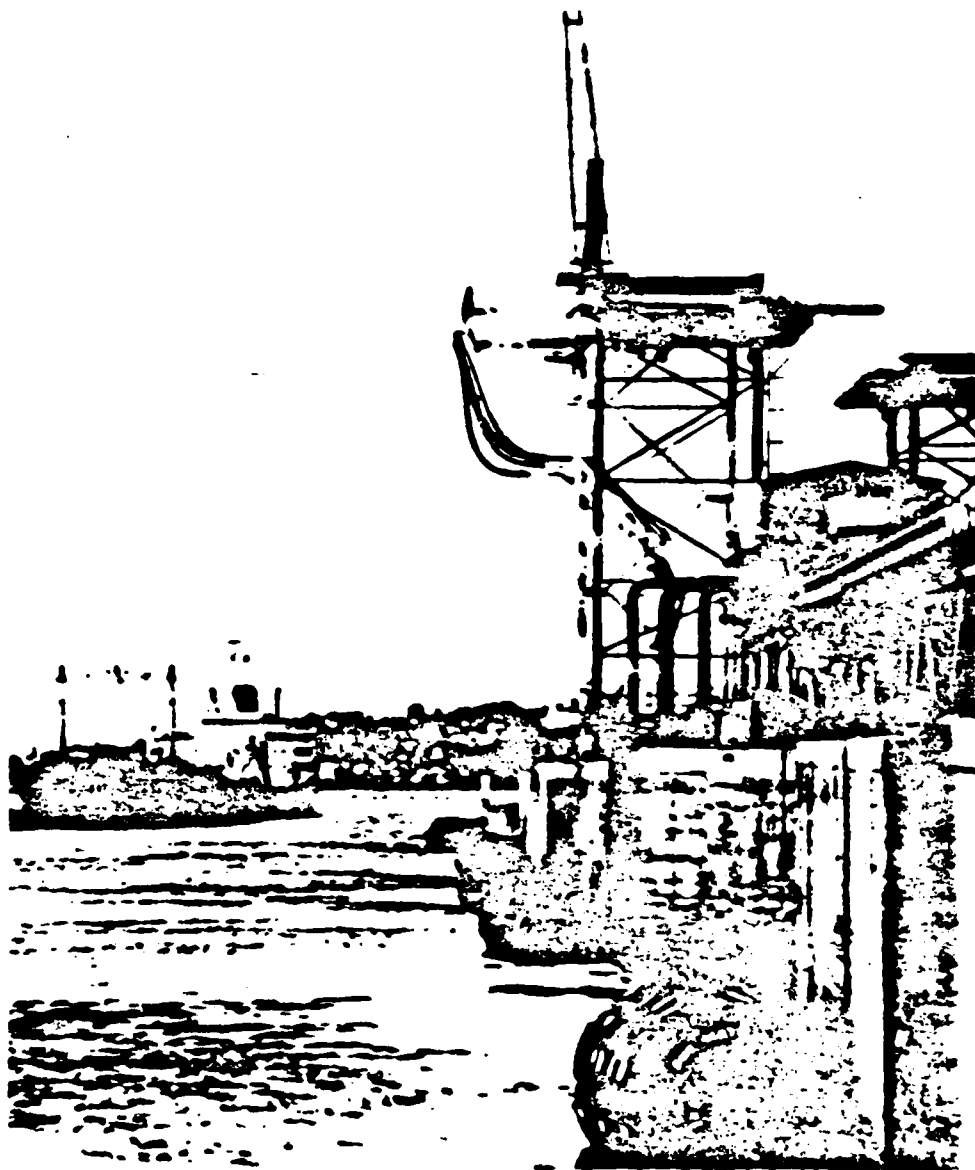
FIG. 22: Pneumatic Fenders (Courtesy of Yokohama)
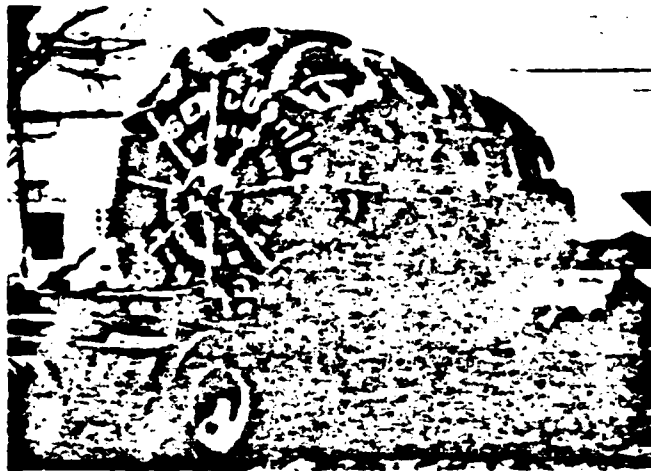
FIG. 23: Anchoring for Pneumatic Fender (Courtesy of Seward)
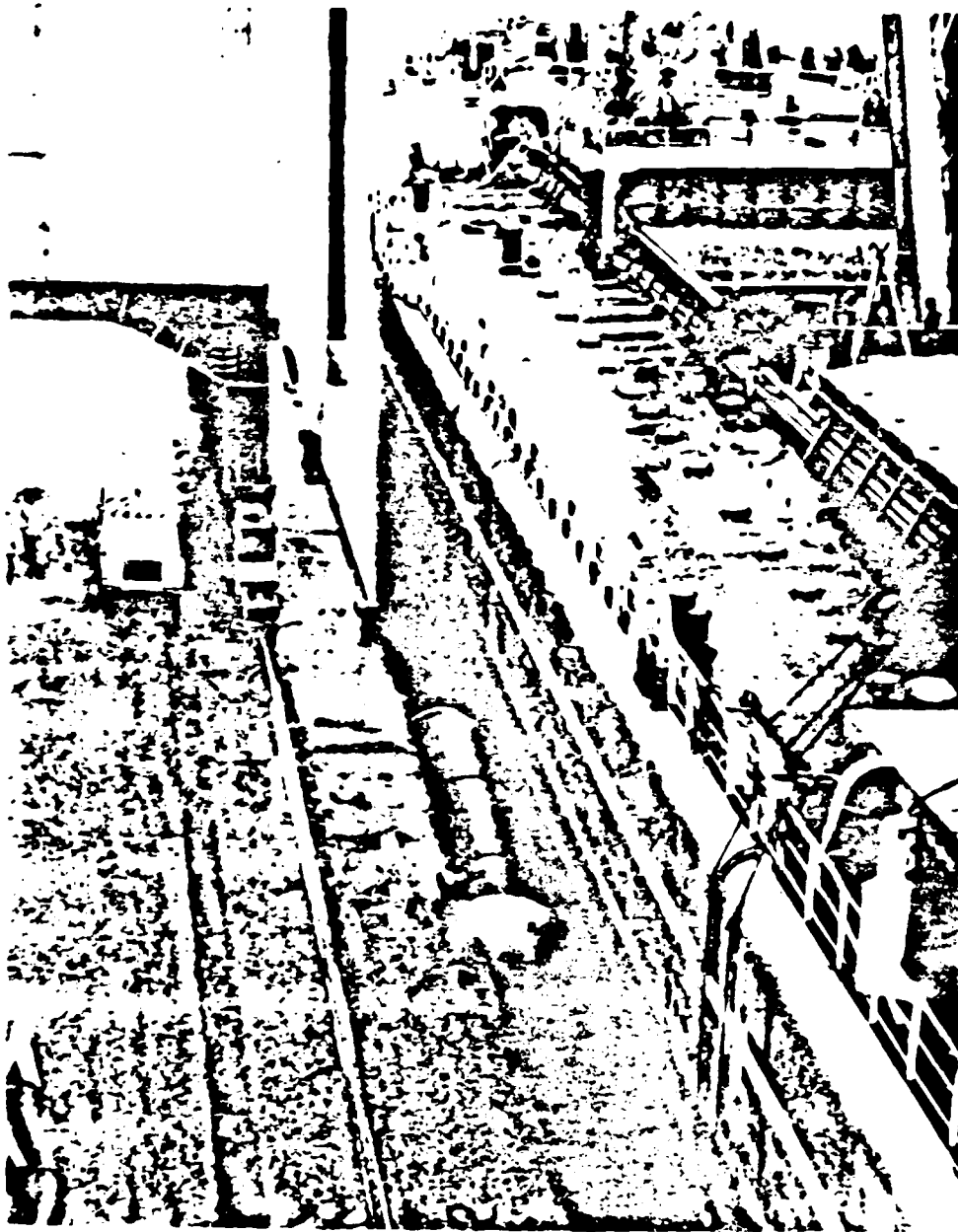
FIG. 24: Foam Filled Fenders (Courtesy of Dunlop)

inoperable. Although repair may be possible on site, the fender is completely out of commission and the dock is unprotected for the length of time necessary to effect repairs. The foam filled fender is unsinkable and, when punctured, will remain afloat and operative until removed for repair. Foam filled and pneumatic fenders have few maintenance problems. Aside from punctures or other accidental damage, the only maintenance required are occasional checks of the fenders themselves and their supporting chains or cables.

GRAVITY FENDERS

Gravity fenders (Fig. 25) consist of a large weight, generally concrete, suspended by chains or cables from beneath a dock structure. Wood facings transfer impact energy from the ship's hull to the suspended weight. The displacement of this weight is the main energy absorption mechanism with additional energy provided by the crushing of timber fibers or deflection of rubber if present. High energy absorption is achieved by long travel of the weight. Due to the size of the gravity fender, it is best suited for exposed locations where the vessel size is large. The rubbing strips must have sufficient "give" to allow the ship to act on the concrete block without damage to the ship's hull. Among the difficulties of the gravity fender are the construction and repair problems inherent in its large size. Heavy equipment is required for both installation and replacement. The suspension system is subjected to not only mechanical wear, but also sea water corrosion and must be maintained. These problems result in both high initial and high maintenance costs. The dock structure required to support the gravity fender may also be expensive to design and construct. The swinging action of gravity fenders has resulted in serious damage to the supporting structure when glancing blows or accidental collisions occur.

HYDRAULIC AND HYDRAULIC-PNEUMATIC FENDER SYSTEM

Hydraulic fenders are of two types: hydraulic-dashpot and hydraulic-pneumatic (Fig. 24). The dashpot consists of a fluid filled cylinder fitted with a plunger which when depressed, forces fluid through a variable of non-variable orifice. The fluid is generally forced to an elevated reservoir so that gravity and the high pressure return the dashpot to its original position once the impact energy is dissipated. The variable orifice changes its cross-sectional area with respect to the plunger travel thereby maintaining a constant reaction force. This system is similar to that used in railroad cars to prevent damage from longitudinal blows. The hydraulic unit is mounted between the dock structure and a flexible fender. The advantages of this system include nearly 90 percent efficiency in dissipation of kinetic energy. The hydraulic system maintains this efficiency over a wide range of velocities, maintains a constant force, reacts with minimum rebound resulting in little or no drift. The adaptability of these fenders allows use in a wide range of conditions by changing the metering system without substituting larger units. Corrosion or severe impact loads may result in serious damage to the unit rendering it inoperative. Repair can usually be eflected without heavy equipment but during the repair period, the only fendering available is that provided by the piles or timber rubbing strips.

Hydraulic-pneumatics are a hybrid form of the pneumatic and hydraulic fenders. A rubber envelope is filled with water or air and water. Energy absorption occurs as a result of viscous resistance and air compression. These fenders are suspended in the same manner as the air-filled and the foam-filled pneumatics and share similar abrasion characteristics.

37

FIG. 25: Gravity Fender (Courtesy of Little)

38

SPRING TYPE FENDER SYSTEM

Steel spring fenders consist of steel springs mounted between the dock structure and a flexible fendering system, either piles or timber frameworks. The most common configuration consists of steel piles framed together with a timber facing of some sort bearing on steel plungers and steel springs. The springs are housed in a metal box with a removable cover to provide easy maintenance and repair of the springs. Maintenance of the springs involves coating, cleaning and corrosion checks. The principle energy absorption mechanism is the compression of the spring with additional energy provided by the deflection of the piles or timber framework. Although some of the installations where steel springs have been employed have provided adequate service, others have experienced difficulty due to failure of the spring as a result of corrosion. The nature of the spring assembly makes this fendering system suitable for exposed sea location and a uniform ship size.

RESULTS AND DISCUSSIONS

The advantages and disadvantages of each type of fendering system as well as its method of operation was explained in detail. These fendering systems as described are utilized in one form or another worldwide. The majority are of vintage years and outdated.

The design methods used for each system are based on the energy-absorption method in which no emphasis is placed on distribution factors. Further, as the ships increase in size and velocity, it has been the trend to increase the size of the fendering system rather than to look for new methods of design or for new systems.

Research at present by the University of Maryland is directed towards an improvement in design techniques and the development of new fendering systems which can satisfactorily handle larger vessels and speeds.

CHAPTER III

MATERIALS

Materials used as bridge protective devices consist of three principle classifications: wood, steel, and concrete. This chapter is concerned with these classifications as they are related to deterioration.

WOOD

Maritime structure constructed of wood have a long, colorful history. While some structures have been an unqualified success, others have met with dismal failure. Those factors which cause damage to the wooden structure shall be discussed in the following order: fungi attack, insect attack, fire damage, chemical damage, impact and overload failures. The various types of wood will also be discussed emphasizing the possible advantages of hardwoods as opposed to softwoods.

Molds, stains, and decay in timber are caused by fungi, microscopic plants requiring organic material on which to live. Reproduction occurs through thousands of small windblown particles called spores. Spores send out small arms which destroy timber through the action of enzymes. Fungi require a temperature of between 50°-90° F., food and moisture. Timber which is water soaked or dry normally will not decay. Molds cause little direct staining because the color caused is largely superficial. The cottony or powdery surface growths range in color from white to black and are easily brushed or planed off the wood. Stains, on the other hand, cannot be removed by surface techniques. They appear as specks, spots, streaks, or patches of varying shades and colors depending upon the organism which is infecting the

40

timber. While stains and molds should not be considered as stages of decay since the fungi do not attack the wood substance in any great degree, timber infected with mold and stain fungi has a greater capacity to absorb water and is, therefore, more susceptible to decay fungi. Decay fungi may attack any part of the timber causing a fluffy surface condition indicative of decay or rot. Early stages of decay may show signs of discoloration or mushroom-type growths (Fig. 26). In some types the color differs only slightly from the normal color giving the appearance of being water soaked. Later stages of decay are easily recognized because of the definite change in color and physical properties of the timber (Fig. 27). The surface becomes spongy, stringy, or crumbly, weak, and highly absorbant. It is further characterized by a lack of resonance when struck with a hammer. Brown, crumbly rot in a dry condition is known as "dry rot". Serious decay problems are indicative of faulty design or construction or a lack of reasonable care in the handling of the timber. Principles that assure long service life and avoid decay hazards in construction include building with dry timber, using designs that will keep the wood dry and accelerate rain runoff, and using preservative-treated wood where the wood must be in contact with water.

Insect damage may result from infestation of the timber members with any of a number of insects: powder-post beetles, termites, marine borers, etc. Powder-post beetles are reddish-brown to black, hard-shelled insects from 1/8 to 1/2 inches long. The life cycle of the beetle includes four distinct stages: egg, larva, transformation, and adult. The adult bores into the timber producing a cylindrical tunnel just under the surface in which the eggs are laid. The larva burrow through the wood leaving tunnels packed with a fine powder 1/16 to 1/8 inch in diameter. Powder-post damage is indicated by this fine powder either fallen from the timber or packed into tunnels within the wood and by the tunnels and holes in the timber. The beetles

41

FIG. 26: Early Stages of Decay at Base of Timber Member
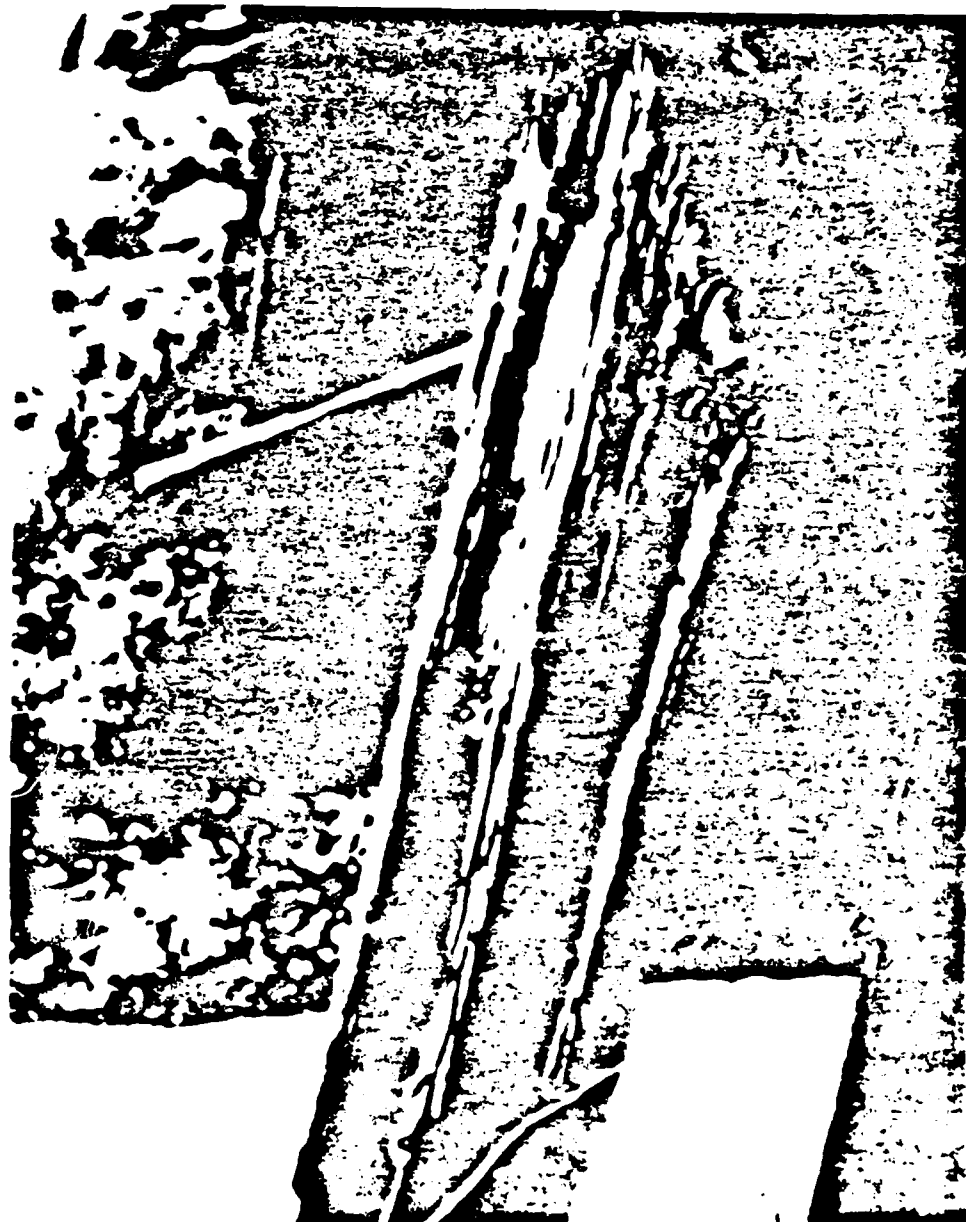
FIG. 27: Advanced Stage of Decay

attack both sound and decayed wood, but are not active in decayed wood which
is water soaked. They may also cause damage by transmitting destructive
fungi from one site to another, thus spreading decay.

Termites resemble ants in size and general appearance and live in simi-
larly organized colonies. Destruction is done by the workers only, not by
the soldiers or winged sexual adults. Subterranean termites are responsible
for most of the damage done in the United States. They are more prevalent
in the southern states, but are found in varying numbers throughout the
states. Termites build dark, damp tunnels well below the surface of the
ground with some of these tunnels leading to the wood which is the termites'
source of food. Termites also require a constant water supply in order to
survive. Subterranean termites do not infest structures by being carried
to the construction site. They must establish a colony in the soil before
they are able to attack the timber. Tell-tale signs are the tunnels in the
earth leading to unprotected timber and swarms of male and female winged
adults in the early spring and fall (Fig. 28). When termites successfully
enter the wood, they make tunnels which follow the wood grain, leaving a
shell of sound wood to conceal the tunnels (Fig. 29). Methods of controlling
termites include breaking the path from the timber to the ground although the
best method is to treat the timber with a preservative.

Wood inhabiting termites are found in a narrow strip around the southern
boundary of the United States. They are most common in southern California
and southern Florida. They are fewer in number than the subterranean termites,
do not multiply as rapidly, and do not cause as much damage. But because they
can live without contact with the ground and in either damp or dry wood, they
are a definite problem and do considerable damage in the coastal states. They
are carried to a building site in timber that has been infested prior to de-
livery, thereby making inspection prior to delivery a necessity. Full length
treatment with a good wood preservative is recommended.
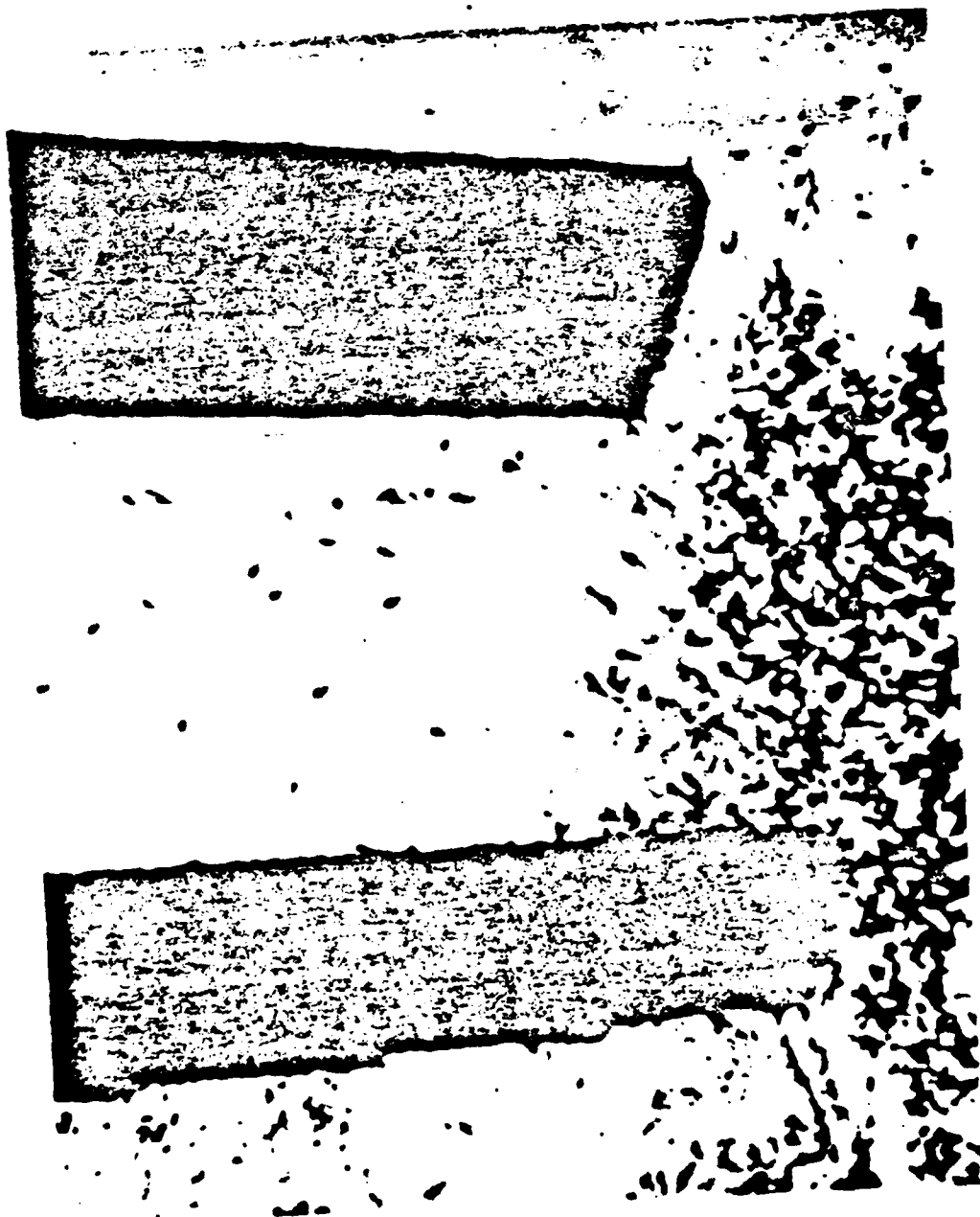
FIG. 28: Swarming Termites

FIG. 29: Characteristic Termite Tunnels

Carpenter ants are usually found in stumps, trees, or logs, but are sometimes found in structural timbers. They range in color from brown to black and in size from large to small. Though carpenter ants are often confused with termites, they can be distinguished by caomparison of the wings and thorax (waist) sizes of the insects. The carpenter ant has short wings and a narrow waist, whereas the termite has long wings and a thicker waist. Carpenter ants use wood as shelter, not food. They prefer naturally soft or decayed wood and construct tunnels which are very smooth and free of dust. Carpenter ants tunnel across the wood grain and cut small exterior openings for access to their food supplies (Fig. 30). A large colony takes from three to six years to develop. Prevention of ant infestation can be accomplished by the use of preservatives along the length of the timber member.

By far the most damaging insect pest is the marine borer (Fig. 31). Borers have been known to ruin piles and framing within a few months. No ocean is completely free of borers and, while some waters may be relatively free, the status of an area may change drastically within a relatively short period of time. The main point of attack is generally between the high tide level and the mud line. Submergence often hides tell-tale signs of infestation so that the first sign of attack may be the failure of the structure. The borers which do the most damage are the mollusks, related to clams and oysters, and the crustaceans, related to lobsters and crabs.

The mollusk borers consist of the "shipworm" teredo, the "shipworm" bankia, and the Pholadidae. There are other types of shipworms throughout the world, but they all live and survive in much the same ways though size and environmental requirements may vary. The teredo has a wormlike, slimy, gray body with two shells attached to the head which are used for boring. Two tubes that resemble a forked tail and normally remain outside the burrow are the only external indications that a shipworm is present. The shipworm

47

FIG. 30: Carpenter Ant Tunnels

FIG. 31: Marine Borers

49

can seal its entrance and thereby protect the burrow from intruders or foreign substances. The size of the teredo varies from 3/8 to 1 inch in diameter and from six inches to six feet in length. The size of the bankia is generally larger than the teredo while other characteristics remain the same. Both types bore tiny holes when they are young and grow to maturity inside the wood. Once the young shipworm has entered the wood, it normally turns down and expands its burrow to its full diameter. Extremely careful observation with a hand lens is required to detect the entrance. The only way to detect the extent of the damage is to cut the wood (Fig. 32) or take borings by some other method. Because the first sign of marine borer infestation may be the failure of timber members (Fig. 33), the shipworm should be considered extremely dangerous. Pholadidae resembles a clam with its body entirely enclosed in a two-part shell. It is a particular danger because it can bore holes up to 1-1/2 inches deep into the hardest timber.

The most common crustacean borer is the limnora or "wood louse". Its body is slipper-shaped from 1/8 to 1/4 inch long and from 1/16 to 1/8 inches wide. It has a hard boring mouth, two sets of antennae, and seven sets of legs with sharp claws. The limnora is able to roll itself into a ball, to swim and to crawl. It will gnaw interlacing branching holes in the surface of the wood with as many as 200 to 300 holes per square inch. These holes follow the softer wooden rings and are .05 to .025 inch in diameter, seldom over 3/4 inch long. As a result, the wood becomes a mass of thin walls between burrows which break away exposing new areas to attack. In this manner the pile is slowly reduced in diameter (Fig. 34). In soft woods like pine and spruce, the diameter may be reduced as much as two inches per year. The chief area of attack is between the low water level and the mud line with occasional activity up to the high water level. The limnora does not seem to be affected by small environmental changes and may be found in salt or brackish water of any temperature, polluted or clean.

FIG. 32: Cross-cut Timber Member Showing Extensive Damage

51
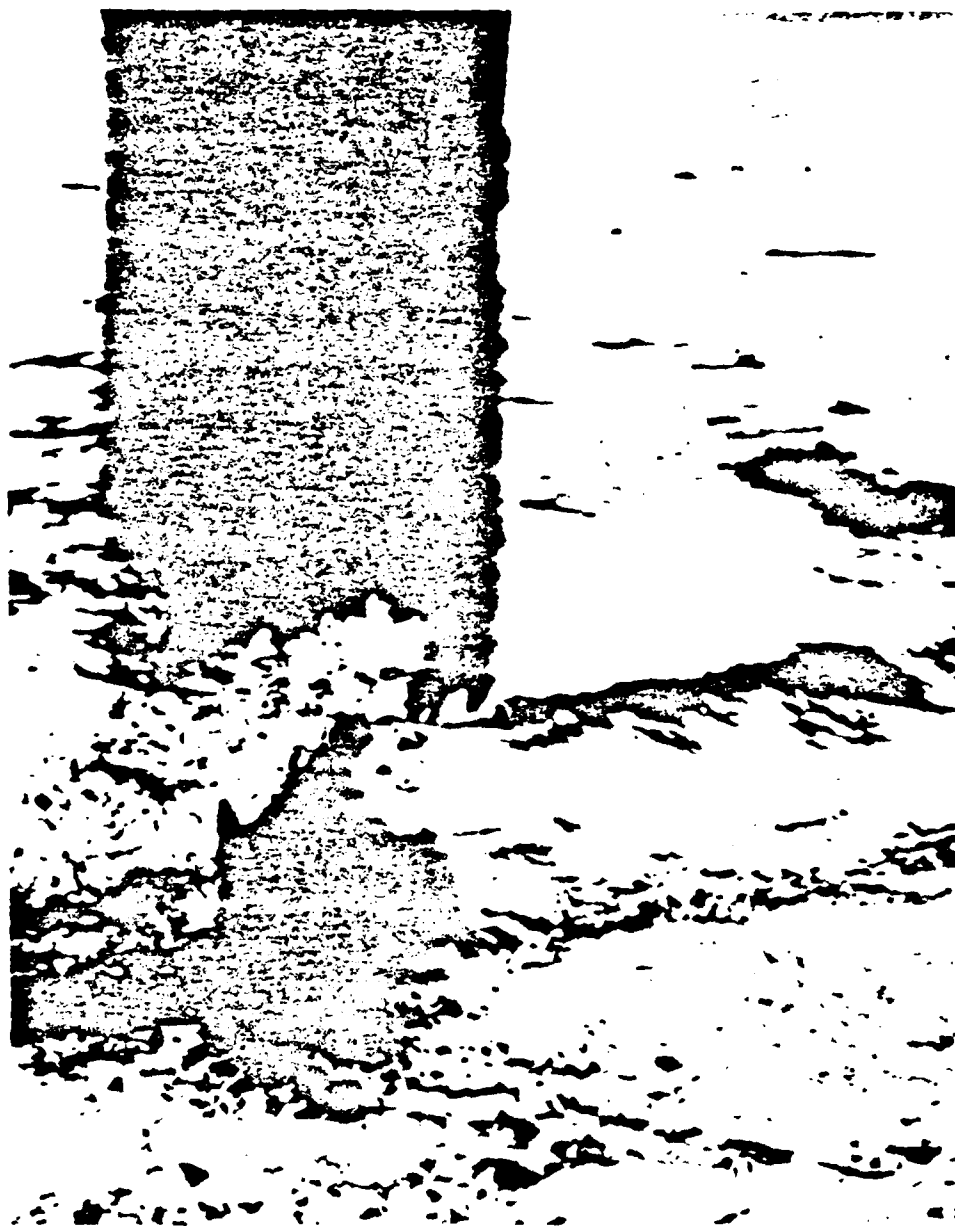
FIG. 33: Insect Attack Resulting in Complete Failure
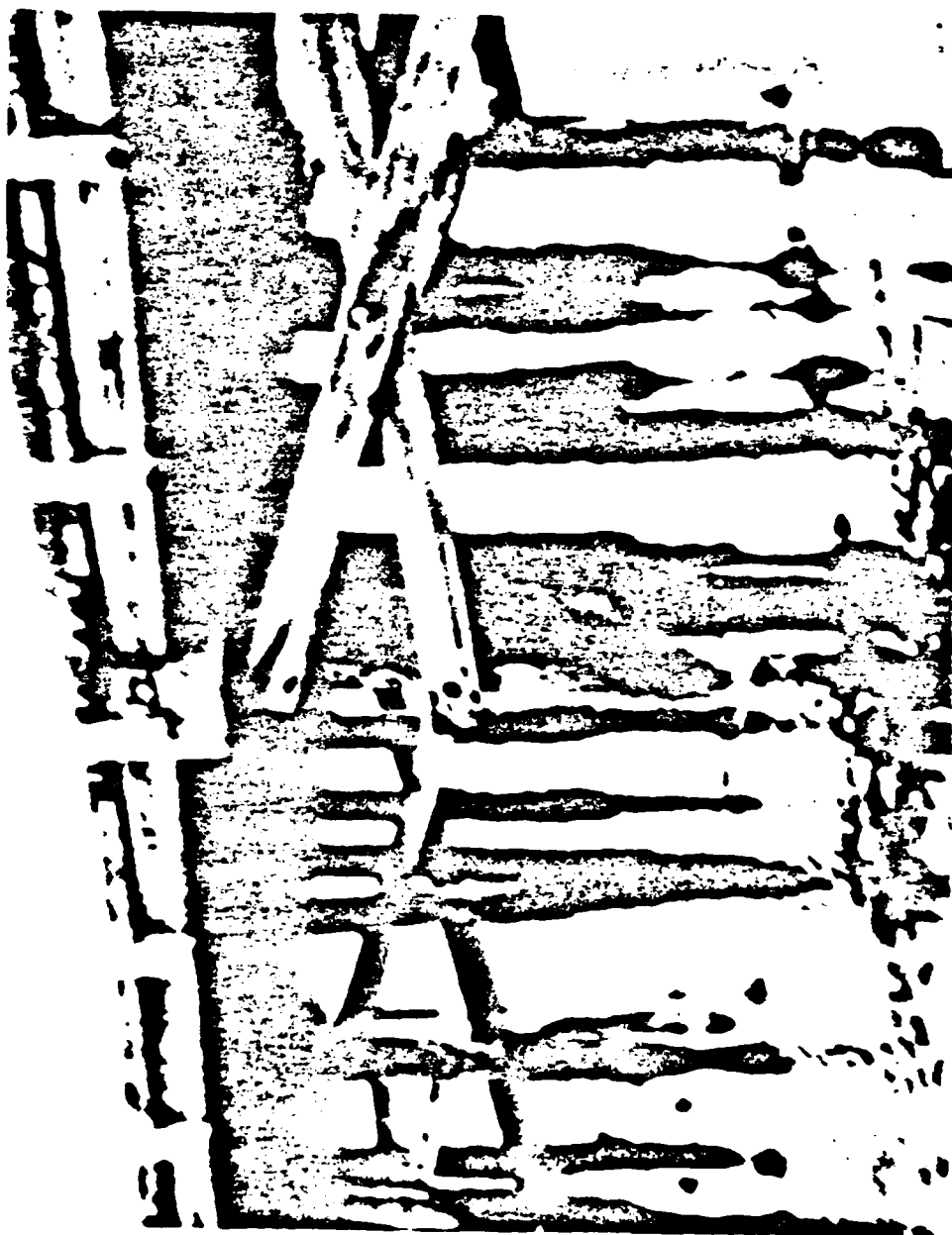
FIG. 34: Reduction at Water Line Due to Insect Attach

Complete protection from borer attack is essential. Metal armoring is falling into disuse as is concrete casing. The very best method may prove to be jacketing creosoted piles. The most practical method involves heavy treatment with high quality, coal-tar creosote by the full cell method to the point of near saturation. Although shipworms will generally not attack a creosoted member, they may attack any area which has been damaged and any untreated area. Limnora attack the creosoted timber directly but at a decelerated rate. Other types of wood preservatives in used include a plastic outer wrap which is successful as long as the plastic is not damaged and cyanide treatment which is messy to apply, leaches out with time, and may, therefore, cause damage to the environment.

Fire damage to wood is a real problem on bridge and wharf structures. Treatment of wood with preservatives may protect the wood from fungi and insect attack but generally results in making the wood more susceptible to fire. Damage due to fire is readily apparent due to the charred appearance and burnt odor of fire damaged wood.

Chemical damage to wood is generally very difficult to determine because it often resembles damage done by other factors. Fungi attack employs a chemical reaction between the enzymes particular to each fungus and the wood fiber. Fire damage involves the oxidation of the wood fiber which is again a chemical process. It is, therefore, important to report any apparent damage to the timber as soon as possible.

Impact damage may occur in the event of a high energy collision between a vessel and a fendering system. Because wood has good impact characteristics, it may show only limited signs of external damage and must, therefore, be inspected carefully after an accident or suspected accident. The timbers may have a shattered appearance as opposed to the sagging appearance caused by overload. Compression failure will resemble wrinkled skin while tension failure looks as if the fibers have been pulled apart.

54

Once provisions have been taken to insure that failure will not occur as a result of the factors discussed above, a wood must be selected on the basis of its material properties. The timber must have a high compressive strength perpendicular to the grain to resist crushing, a high degree of fiber hardness to resist rubbing action but not to the point that brittleness and checking result, and a relatively high bending strength. In general, Douglas fir, Southern pine, White oak, and Red oak are commonly used in the United States. These woods must be protected in the manners discussed earlier, but have good workability, are generally readily available and inexpensive. Douglas fir is the only structural timber from which high quality piles of 100 foot lengths can be obtained.

Various hardwoods have been used in fendering and include several exotic species with natural borer resistance. Greenheart is the most common of these woods and is available in various thicknesses and lengths. It is expensive. Tropical timbers tend to be much harder than the soft woods and cannot be worked with ordinary tools intended for soft woods. Metal working tools are necessary as are pre-drilled holes. This extreme hardness may result in splintering of the timber fiber. Greenheart is heavier than water resulting in additional construction difficulties, but has a service life more than three times that of oak members.

The choice of Greenheart or the softer woods must be based on economic, construction, preservation, and service life considerations. There is no single solution to this debate. The choice must be left with the designer and the engineer who have knowledge of the peculiar problems of their design site.

STEEL

Steel is a material which has a life long high compressive and tensile strength, but its use in marine structures is limited.

Man's concern with the corrosion characteristics of metals used in maritime works dates to the fourth and fifth centuries B.C. It was observed that while most metals used in ships deteriorated in some way when exposed to sea water, bronze showed little or no corrosion. Since the use of bronze in marine installations is not feasible now or in the near future, methods must be found for protecting the metal most commonly used in these structures, steel, from salt sprays, tidal action, and other environmental factors.

Corrosion refers to the conversion of metals into compound forms as a result of some natural mechanism. The most common types of corrosion are galvanic, differential environment or concentration cells, stray current, bacteriologic, stress, fretting, impingement, and chemical corrosions. Galvanic corrosion requires an electrolyte, sea water, and two dissimilar metal coupled together, one of which will corrode. The corroding area is referred to as the anode, while its counterpart is the cathode. The process involves the flow of current from the anode, which will corrode, to the cathode, which is protected. Certain metals have been used as anodes to steel: magnesium, zinc, and aluminum to name a few. The order in which joined metals in an electrolyte will corrode is determined by the voltaic potential of the metal. Magnesium will corrode to all other metals. Zinc will corrode to all other metals except magnesium. Aluminum will corrode to all other metals except magnesium and zinc, etc. Corrosion producing galvanic cells may occur in the same metal. Steel is anodic to mill scale found on hot rolled steel products such as steel piling. Bright surfaces are anodic to matte surfaces. Stressed surfaces are anodic to normal surfaces. In addition, surface imperfections and non-homogeneous metal may cause galvanic cells.

Differential environment corrosion occurs when a metal such as steel is in contact with an electrolyte which is non-homogeneous from point to point or varies in concentration along the surface of the metal. Some of the major environmental conditions which may cause corrosion cells to develop on steel pilings include varying salt conditions in the soil in contact with the pile, varying moisture conditions in the soil in contact with the pile, different oxygen concentrations in various horizons of the soil or water in contact with the pile, and foreign matter embedded in the soil in contact with the pile such as cinders or pieces of metal. Within the area of tidal fluctuations, the oxygen content varies considerably between the high and low tide levels and the low tide and ground levels. Current flows from the low oxygen to the high oxygen content area resulting in corrosion in the low oxygen or anodic area. Protruding elements, corners, and weld points tend to corrode faster than the surrounding surface metal because the interruption of flow results in development of an oxygen concentration cell. In those areas where fresh water meets sea water, corrosion of steel piles are likely. The higher oxygen content of the fresh water causes current to flow from the salt water area to the fresh water area producing anodic conditions in the salt water and subsequent corrosion of steel pilings in the salt water area.

Stray electrical current corrosion is an electrochemical process similar to galvanic and differential environment corrosion. It is the result of stray electric currents from electric railways, railway signal signs, cathodic protection systems for pipelines or foundation pilings, DC industrial generators, or DC welding equipment. Since metals are more conductive than water or soil, stray currents tend to collect in the metal, following the path of least resistance. Corrosion occurs when the current leaves the metal producing stray current electrolysis at the point where the current exits the metal. While stray alternating currents are generally not harmful to underground or

underwater structures, the current can be rectified by passing through or off metal structures. The partial DC component is then capable of producing current electrolysis, as discussed earlier. The sources of alternating current include central power stations and large substations.

Bacteriological corrosion is caused by two types of micro-organisms, anaerobic and aerobic. Of the two types, the anaerobic is the most responsible for the corrosion of steel. This corrosion results from the creation of concentration cells on the surface of the metal, the creation of a corrosive environment through water and decomposition, and depolarization of cathodic or anodic areas. Corrosion due to this particular type of organisms may be found in bogs, heavy clay, swamps, stagnant waters, and contaminated waters, particularly when contaminated with the waste from paper-making operations. The external corrosion products are black underlain with a thin film of white substance.

Stress corrosion requires high stress in most instances although this may vary with the environment. The stress may be residual stress from cold working, or may be due to applied loads or welding operations. Tensile forces expose metal at the grain boundaries resulting in small intergranular cracks. As the corrosion continues along the grain boundaries, the combination of stress and continued corrosion results in transgranular cracking.

Fretting corrosion occurs on closely fitted metal parts which are under vibration such as a sleeve on a shaft, shrunk metal fittings, or forced metal fittings. The contact surfaces may become pitted and a deposit, usually red in color, may form at the interface. The corrosion damage affects operating tolerances and increases the possibility of failure.

Impingement corrosion affects brass and hard drawn copper and is, therefore, of little concern when dealing with maritime installations.

Chemical corrosion resul' from the direct attack on steel by acids or diluted acids. Chlorine, carbon dioxide, and sulfur oxide are atmospheric contaminants which may cause the formation of acid films on metal surfaces resulting in rapid corrosion. Chlorine is more commonly found in the marine environment while carbon dioxide and sulfur oxide are common industrial contaminants.

The rate of all of these corrosion reactions is directly affected by the concentration of dissolved oxygen in the water, the concentration of corrosion products in the water, and environmental factors which may affect the condition of the electrolyte such as temperature, salinity, etc. The most rapid corrosion occurs in the tidal fluctuation zone where dissolved oxygen is plentiful and the moving water body prevents saturation of the water surrounding the metal with corrosion products or the deposition of corrosion products on the surface of the metal.

In many instances the failure of a steel structure in sea water could be prevented by thorough design investigations and considerations. These considerations should include the selection of materials to suit the environment, the minimum galvanic potential between two metals, the relative areas of dissimilar metals which are to be joined, the resistivity of the soil and water surrounding the metals, the possibility of applying insulating coatings, and the prevention of water accumulations where feasible. These design criterion may reveal the need for external coatings applied to the surface of the steel members.

Coatings may take many forms: metallic coverings and claddings, organic coatings and wrappings, synthetic organic materials, and concrete casings. Metallic coverings and claddings protect the base metal in two ways depending upon the position of the applied metal in the electromotive force series. If the applied metal is more corrosion resistant than the base metal, the

59

applied coating is referred to as sacrificial and will corrode to provide
protection for the base metal. Sacrificial coatings consist of zinc or alum-
inum. Organic coatings and wrappings resist moisture absorption and isolate
the metal structure over long periods of time from the forces of electricity.
Some of the common organic materials used as coatings and wrappings include
asphalt, coal tar, paints, plastic wrappings, and greases. Of interest in
recent years has been the effect of oil spills on the corrosion resistance
on metal structures. Oil films which develop on the structures provide ex-
cellent protection from corrosion by isolating the structure from air and
water. This method of protection tends to be too costly to be used as a
systematic corrosion preventative. Synthetic organic materials have been
widely used for electrical insulation and isolation. Plastics are also used
in the protection of pipelines from underground corrosion and at the joining
points of dissimilar metals to prevent current flow. Concrete casings are
the last area of external applied protection. The characteristics of the
concrete necessary to insure adequate protection is discussed in the section
of this chapter dealing with concrete corrosion. The concrete may take the
form of shotcret or gunite but must have a minimum depth of cover of three
inches. External coatings tend to deteriorate with age resulting in checking,
flaking, scaling, chalking, washing, blistering, peeling, cracking, or spalling.
They may, however, be the most economically feasible method of protection for
a particular structure.

Cathodic protection refers to the protection of steel or other metals
through electrolysis by stray electric currents. There are two methods of
cathodic protection, sacrificial and impressed current; each uses a base metal
which is corroded instead of the steel in the structure. In the sacrificial
system the metal to be protected is wired to a more negative metal and both
are placed in an electrolyte, either soil or water. Current flows from the

anode to the cathode, from the more negative metal to the less negative metal
resulting in the corrosion of the anode and protection of the cathode. Mag-
nesium and zinc are commonly used in the sacrificial system. The impressed
current system requires an external power source and anodes consisting of
any conducting material suitable for the purpose. Current flows from the
anode connection to the power supply to the cathode which is a relative ground.
The variable power source provides a wide range of voltage and current possi-
bilities although the entire system is subject to failure due to power fail-
ures. The required maintenance and inspection of the impressed system is far
greater than that required by the sacrificial system. The sacrificial system
is relatively simple to install and maintain. Additional anodes can be added
without revamping the design for the entire system. Both systems are effec-
tive in protecting those portions of the structure which are constantly im-
mersed in water or imbedded in the ground. Neither system is effective in
the splash zone, the area of greatest corrosion, or above water or ground
level.

To insure the greatest protection in the splash zone, heavy concrete
casings and/or corrosion resistant metal shielding are recommended. Further
research into effective corrosion prevention methods should pay special at-
tention to splash zone protection and feasibility of application in areas
where little maintenance is likely to be performed.

Good maintenance of the structure can make or break any protection sys-
tem yet devised. The controlling variables in atmospheric corrosion are the
length of time that the metal is wet; the amount of foreign matter in the at-
mosphere, particularly chlorine, sulfur, and carbon dioxide which form acid
films; and the composition of the metal. Proper maintenance can do little
as far as controlling the composition of the metal or the foreign matter in
the atmosphere, but it can affect the length of time that the structural

members are wet. Structural members can be kept free of dirt and debris which retain rain and wash water as well as the deicing salts which may be present, and may even absorb moisure and corrosive particles from the atmosphere. The water and salts absorbed by the dirt and debris is held in contact with the metal for long periods of time resulting in accelerated corrosion.

Deterioration of a steel structure may result from processes other than corrosion although for fender systems corrosion is of primary significance. Fatigue cracking may occur at connections and points on the structure where a discontinuity or restraint is introduced; at loose connections or members which could force a member to carry unequal or excessive stress; at damaged members, regardless of magnitude, which are misaligned, bent or torn; at sites where corrosion could reduce load carrying capacity through decrease in the member section making it less resistant to both repetitive and static stress conditions; at weld points where crack initiation might begin; at sites of part repair and areas of excessive vibration or unusual twisting; and at places where structural details are known to have exhibited fatigue problems. The effect of high temperatures on steel strength becomes of importance when considering the possibility of fire on a dock or pier structure. During regular operating conditions, the temperatures remain within the realm of elastic design and pose no unusual design problems. Careful inspection of the structure can generally reveal areas of fatigue cracking or plastic failure due to high termperatures.

CONCRETE

The use of concrete in marine structures has increased in recent years as the size of berthing vessels has increased. Concrete has high compressive strength but low shear and tensile strength. It is porous, extensible, and fire resistant, but can be damaged by intense heat. Under ordinary loading

conditions, concrete is elastic though it will creep under sustained, heavy loads. The shear and tensile strength of concrete can be increased by the addition of reinforcing bars or by prestressing with steel wires which are under tension. This factor allows much design flexibility yet deterioration of concrete in the marine environment can pose significant problems.

The factors which cause deterioration may be grouped under the following areas: poor design details, construction deficiencies and operations, temperature variations, chemical attack, reactive aggregates and high alkali cement, moisture absorption, wear or abrasion, shrinkage and flexure forces, collision damage, scouring, shock waves, overstress, fire damage, foundation movement, and corrosion of reinforcing bars and prestressing wires. The visual symptoms of deterioration consist of cracking, scaling, spalling, rust stains, surface disintegration, efflorescence and exudation, and vehicular damage. Each shall be examined with the form of deterioration most responsible for that form of disintegration.

Poor design details which can cause concrete to crack include insufficient drainage. Scuppers may not be provided or improperly provided with downspouts to keep the water discharge away from concrete surfaces including caps and decks. The scuppers may be too small and, as a result, easily clogged. They should be provided at all low spots. Weep holes, if provided, may be too small, too few, or discharging over another concrete surface. When not enough space is provided at an expansion joint, spalling may result (Fig. 35). Insufficient cover over rebars may cause corrosion of the rebars, or, in the case of prestressed concrete, the prestressing wires. Of all of these considerations, the need for sufficient expansion space cannot be overstated.

Construction deficiencies may result in concrete deterioration regardless of the care taken in the design procedure. Soft spots in the subgrade of a foundation will cause settlement resulting in cracking (Fig. 36). If formworks

63

FIG. 35: Spalling at Expansion Joint

FIG. 36: Cracking Due to Foundation Settlement

are removed between the time the concrete begins to harden and the specified time for formwork removal, cracks will probably occur. These cracks are especially dangerous since they may occur internally with no external manifestations. Water can collect in these cracks and cause spalling due to freezing and thawing or cause corrosion of any internal steel which may eventually lead to cracking and spalling. If sufficient spacing does not exist between rebars in reinforced sections, voids may develop if the mix is not properly vibrated. These voids collect water with end results similar to those discussed earlier for cracks which collect water. Excess vibration may cause segregation of the concrete mix, resulting in a weaker concrete than specified. The inclusion of clay or soft shale particles in the concrete mix will cause small holes to appear in the surface of the concrete as these particles dissolve. These tiny holes increase the porosity of the concrete and, as before, lead to cracking and spalling and possible corrosion of the internal steel (Fig. 37).

Freezing and thawing (temperature variation) is a common cause of concrete deterioration. Porous concrete absorbs water which expands as a result of freezing. The internal expansive pressures developed in this manner often produce cracking (Fig. 38), spalling (Fig. 39), or scaling. Scaling appears as a chalky matrix typically white. Temperature fluctuations may further affect concrete integrity if the coefficient of thermal expansion differs significantly from that of the mortar. Aggregates with lower coefficients may cause high tensile stresses resulting in cracking and spalling. Further problems arise if the concrete section is restrained from expansion or contraction. The internal forces set up under these circumstances are sufficient to result in cracking and spalling and eventual failure of the member.

Chemical attack of concrete may come from two sources. The use of salt or chemical deicing agents contributes to weathering through recrystalization, and salt may increase the water retention. The results are similar to the

66

FIG. 37: Surface Pitting Due to Included Clay
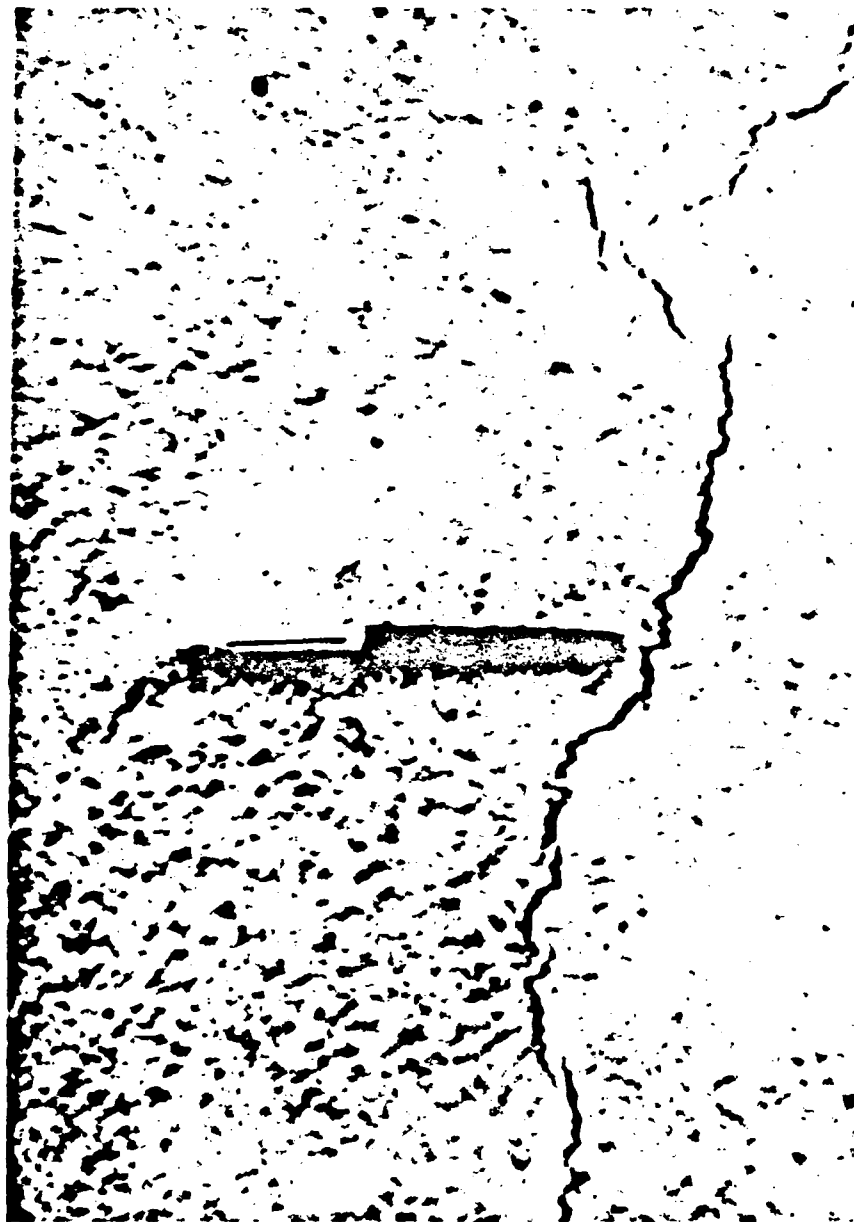
FIG. 38: Freeze-Thaw Cracking
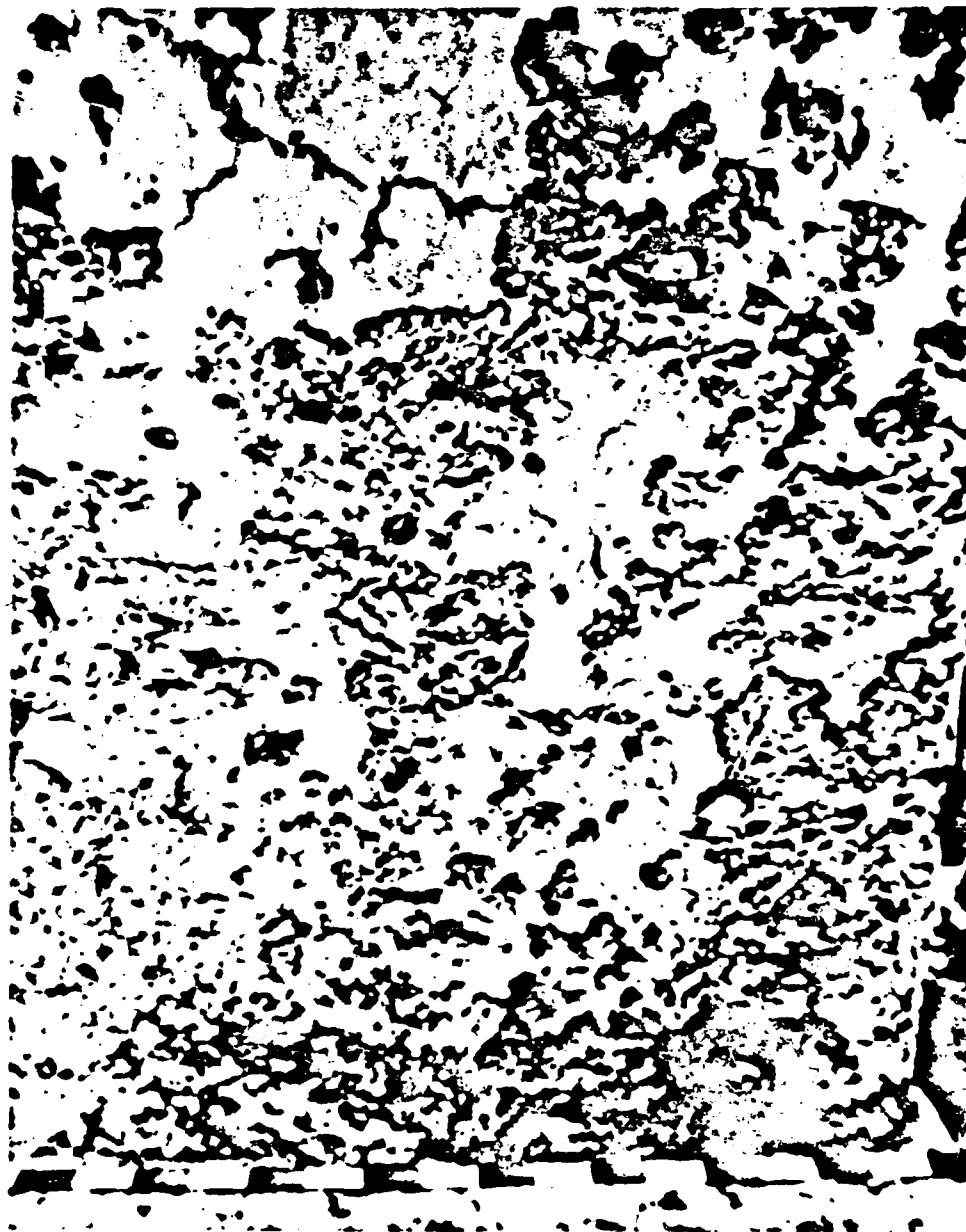
FIG. 39:   Surface Deterioration

effects of freezing and thawing: cracking and spalling. Further chemcial attack may come from chemicals in the soil or water surrounding the concrete members. Ammonium and magnesium ions react with the calcium in the cement paste. Sodium, magnesium and calcium sulfates react with the tricalcium aluminate in the cement paste. Acids will attack the cement paste by chemically transforming the composition of the paste. The results of general chemical attack appear as surface disintegration in the form of scaling and spalling, random cracking in unrestrained members, swelling and parallel cracks in compression members, and protruding aggregate resulting from the removal of cement paste.

Reactive aggregates and high alkali cements cause swelling, map cracking (Fig. 40), and popouts (Fig. 41).

Moisture absorption will cause concrete to swell. Concrete cylinders, thirteen feet in diameter, have grown as much as six inches in a marine environment. If restrained, the restraining material will break apart or the concrete will crack and spall. In addition, soft water will tend to leach out the lime in the cement and leave a powdery residue.

Wear and abrasion cause the surface of concrete to disintegrate over extended periods. Wind and water-driven particles, particularly sand, play a significant role in abrasion near the mud line and above the high water line. Piles may be damaged due to the rubbing action of vessels resulting in scaling, revelling, and cracking at joints, and scarring.

Shrinking and flexure forces, common design considerations in concrete piles, may set up tensile stresses exceeding the capacity of the section. The end result is cracking. Setting shrinkage generally causes shallow surface cracking (Fig. 42). Drying shrinkage may take place over extended period of time producing tensile forces and eventually cracking. The time frame may amount to several years.

FIG. 40: Map Cracking
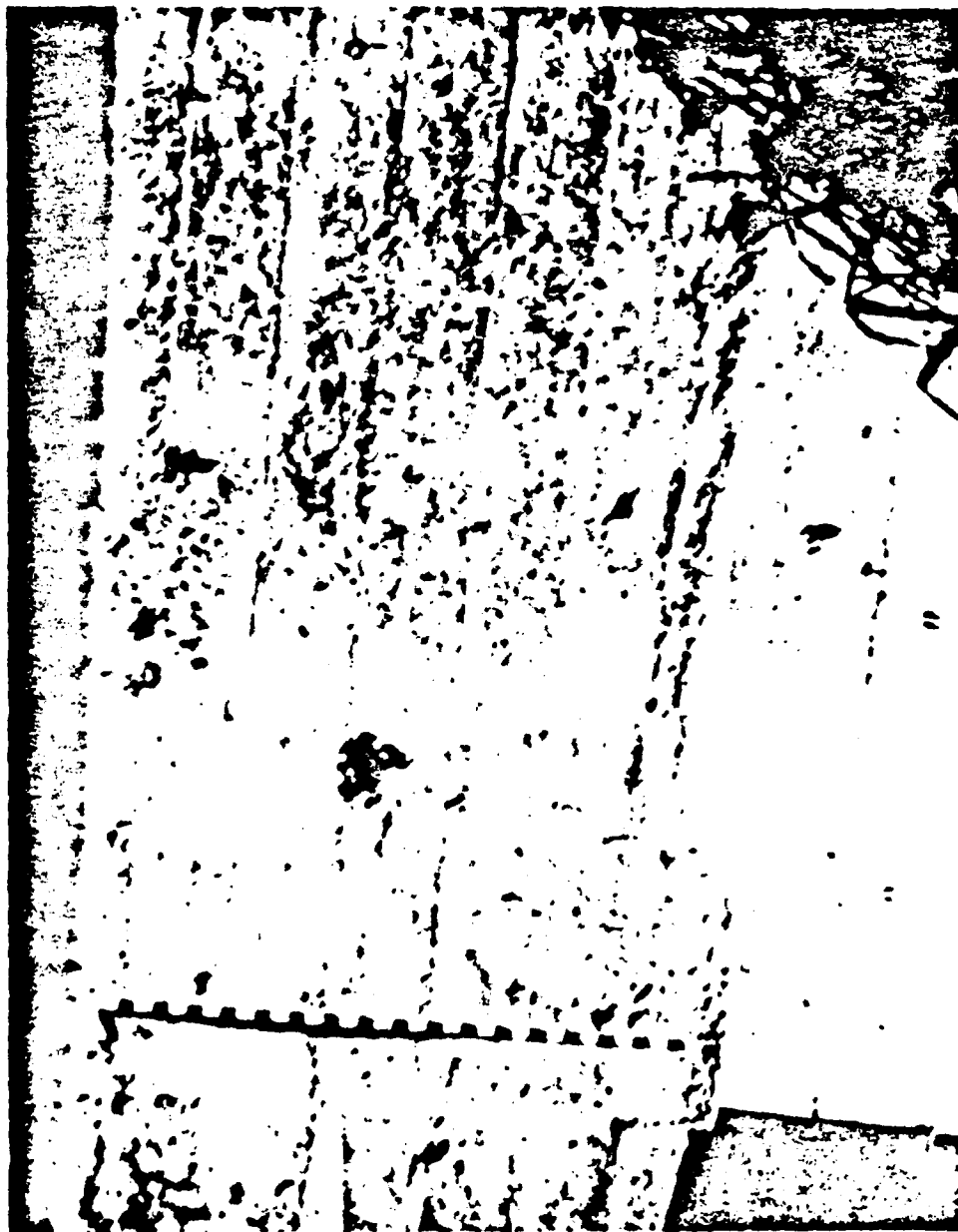
FIG. 41: Popouts Due to Reactive Aggregates
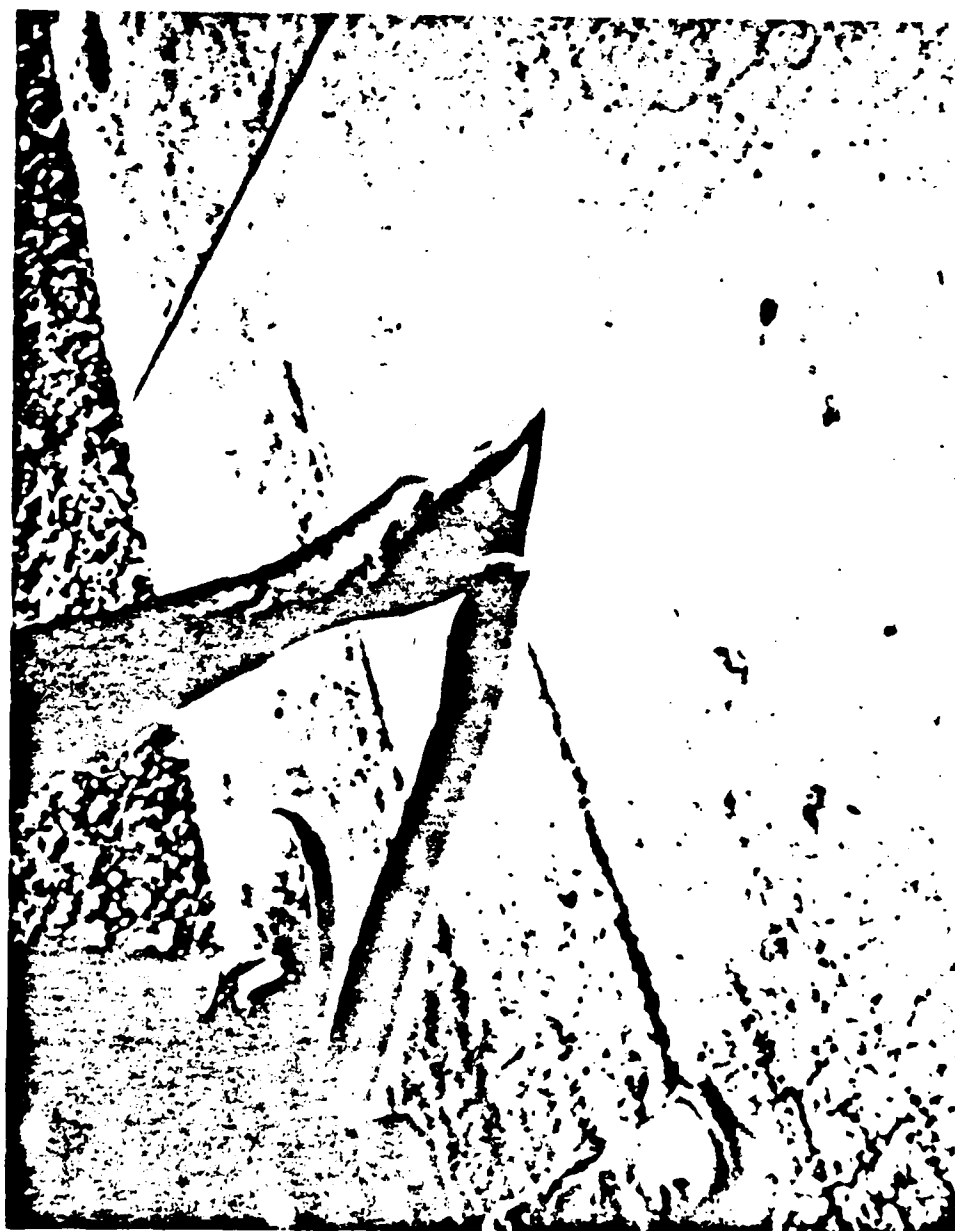
FIG. 42: Shallow Surface Cracking

73

.Collision damage is generally considered to be an accidental occurence.
Any concrete structure which can be reached by a moving vehicle has suffered
collision damage at some time. In most instances the vehicle is more severe-
ly damaged than the structure. After accidental collisions the structure
should be inspected for possible damage.

Concrete surfaces in surf zones are scarred by sand and silt (Fig. 43).
Ice flows in rivers and bays are also responsible for considerable damage to
concrete pilings and piers (Fig. 44). Most damage of this type occurs between
the low and high water marks.

A shock wave can damage concrete due to the varying transmission rates
through the aggregate, the paste and the reinforcing steel. The shock waves
then become partially additive setting up conditions leading to cracking and
spalling of the concrete mass. Concrete piles are vulnerable to damage from
shock waves while they are being driven.

Overstressed concrete may exhibit longitudinal and lateral cracking in
a deck. Over a bearing point there may be diagonal cracking at the end of
a simple beam (Fig. 45), vertical cracking running from the bottom at the
center of a simple beam to the neutral axis, and vertical cracking from the
top of the beam extending downward to the neutral axis for a beam which is
continuous over the bearing area (Fig. 46).

Fire damage results from the extreme temperatures of a large fire. Tem-
peratures above 300° C. will cause a weakening in the cement paste and lead
to cracking and spalling (Fig. 47).

Foundation movements will cause serious cracking in concrete structures
if they generate a sizeable tensile stress in the concrete piers or abutments.
Vertical cracking predominates.

Corrosion of the internal reinforcing steel causes tremendous expansion
pressures in the concrete. Fully corroded steel occupies seven times the
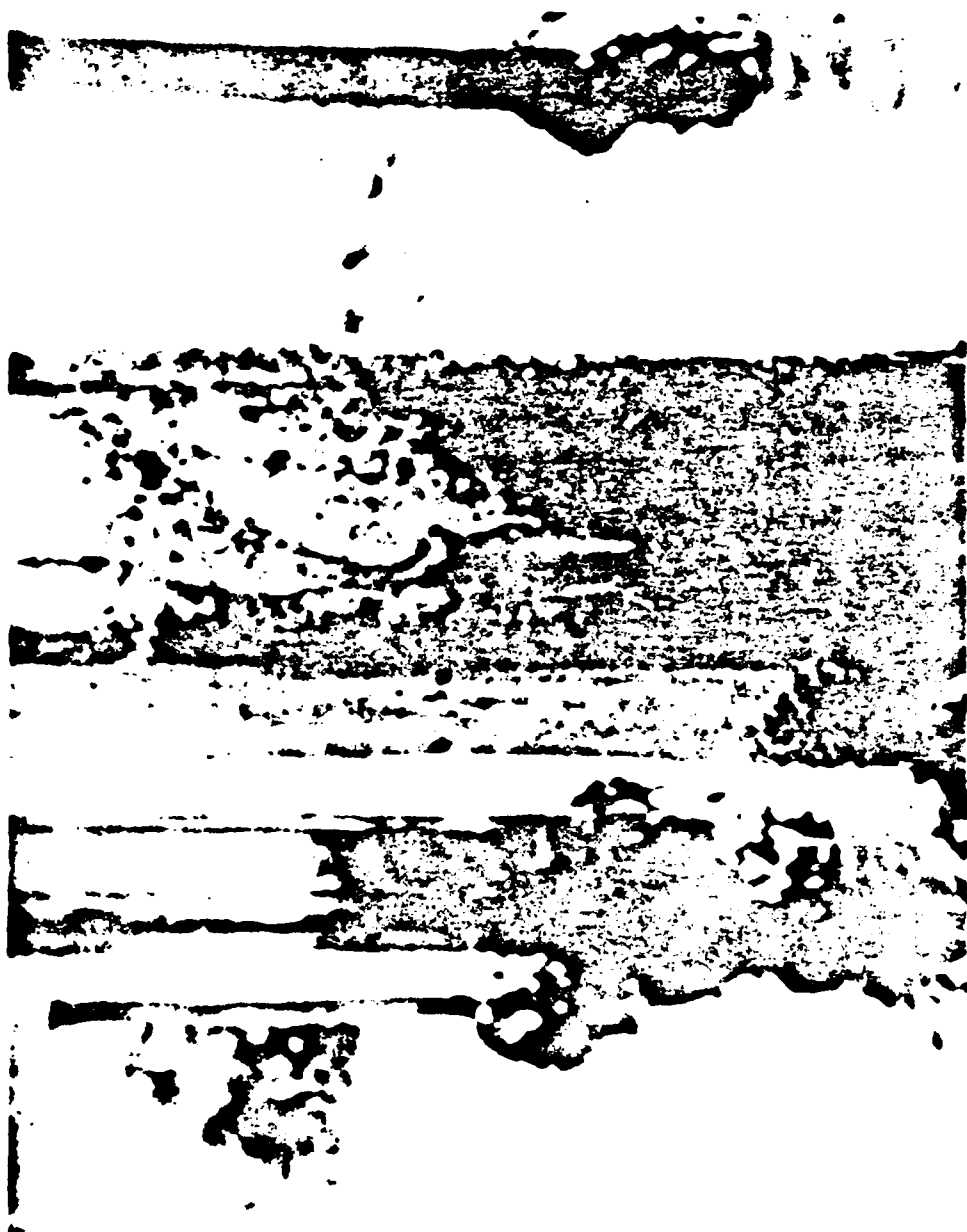
FIG. 43: Sand and Silt Scarring

FIG. 44: Total Removal of Concrete Matrix from Reinforcing Rods Due to Ice Flow

76

FIG. 45: Diagonal Cracking

FIG. 46: Concrete Member in Models Lab

FIG. 47: Cracking and Spalling Due to Fire
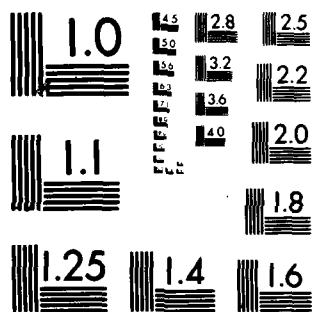
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1964 A

volume of uncorroded steel, therefore, cracking and spalling result from the volume increase (Fig. 48). Corrosion of the steel may also result if water finds its way into the concrete member.

Corrosion of the prestressing wire combined with the high tensile stres required for prestressing may result in failure of the member due to stress-corrosion. Failure of a significant number of prestressing wires in this manner will result in loss of tensile strength in the member and could lead to failure under heavy loading conditions. Further deterioration of the ter sile strength of a member may result from creep of the prestressing steel, shrinkage of the concrete causing a relaxation in the prestressing wires and creep of the concrete, shortening the overall length of the member and there relaxing the prestressing wires. Other causes for a loss of prestress incl elastic deformation of the concrete, drawing in of the anchorages, and friction loss in the post-tensioning operations. The combined loss of prestres due to such causes can amount to as much as 25 percent to 35 percent of the member's design strength. The result of loss of prestress is cracking particularly near the anchorages and on the compression face. Unlike cracks in high tension areas of reinforced concrete members, the appearance of cra in a prestressed member may have serious effects on its structural integrit A prestressed member is usually under high compressive stresses, consequent cracking should not be expected.

With proper design mixtures, it is possible to produce concrete with s vice life of fifty years in a marine environment. The concrete should be dense with an impervious surface and relatively nonabsorbent characteristic All internal steel should be covered to a depth of at least three inches of good concrete. The cement content should range between a minimum of 6-1/2 sacks per cubic yard and a maximum of 7-1/2 per cubic yard. The aggregates should be graded for maximum density and nonreactive. If nonreactive aggre
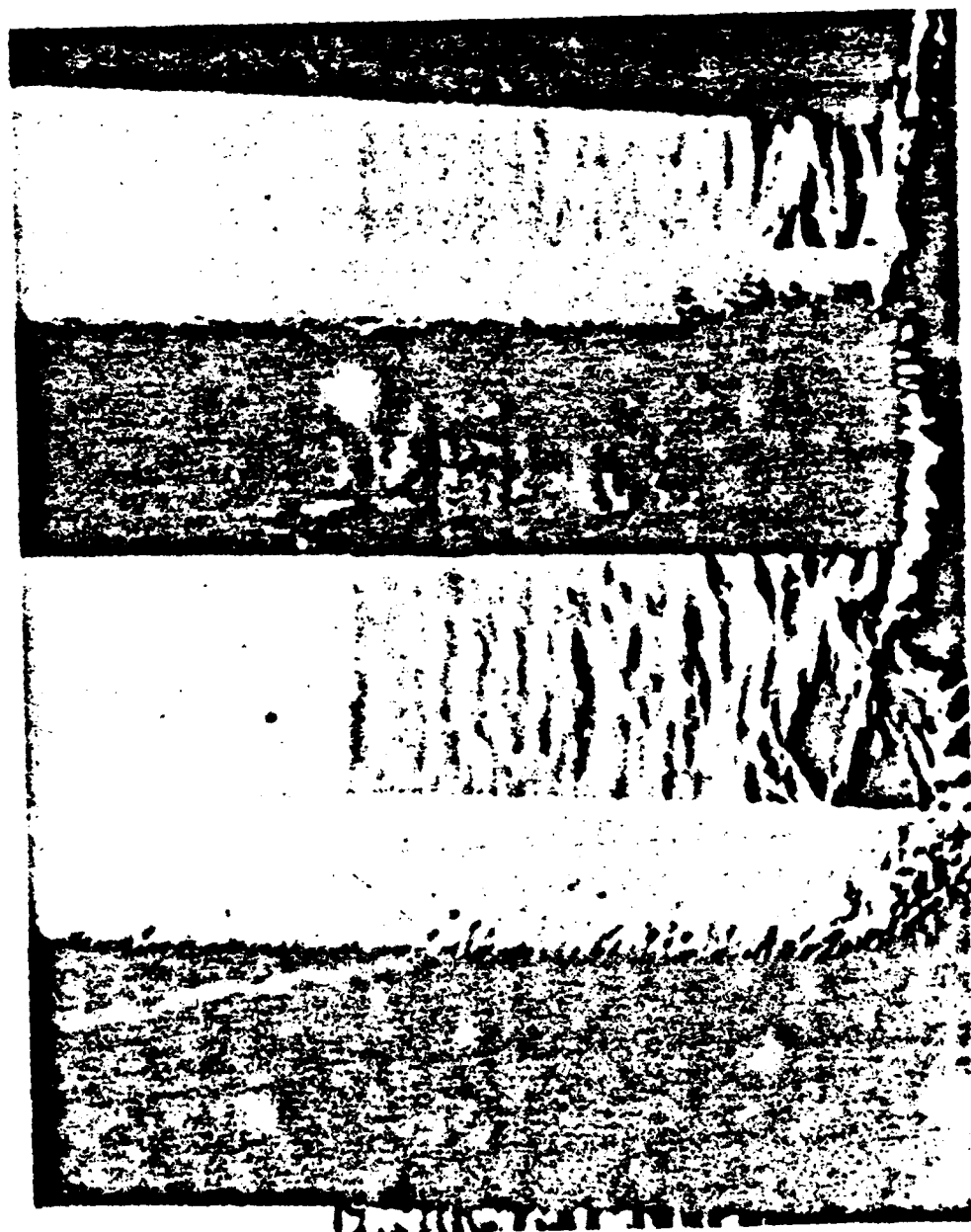
FIG. 48: Piles Cracking

are not available, then pozzolans must be added to the aggregates or a low-alkali cement must be used. The water content should be such as to provide a workable, plastic mix with the lowest water-cement ratio possible, not to exceed six gallons per sack of cement. Type V cement with five percent maximum tricalcium aluminate should be used although Type II may be substituted under tight economic conditions. Three to six percent entrained air is usually specified for aggregate size ranges from 1-1/2 to 3 inches. Thorough curing by the best means possible and adequate vibration is necessary to insure the concrete reaches its design strength. Particular care should be taken when handling precast members. Support is necessary along the entire length of reinforced members due to low bending strength. Prestressed members are less susceptible to handling stresses than ordinary reinforced members but should be treated with some degree of reasonable care.

Other forms of concrete used in the marine environment include asphalt impregnated concrete. The outer shell of the concrete is impregnated to a depth of about one inch to three inches or more. The method of application resembles that for creosoting wood. The concrete is placed in a bath of molten asphalt admitted under high vacuum after being pre-dried at temperatures up to 250° F. The member is then subjected to air pressures up to 150 psi. The asphalt is then removed and the concrete is exposed for several hours to pressures of 100 psi. It is then removed to a cooling chamber. During the entire process the temperature gradient is closely watched. Asphalt impregnated beams and cylinders have been found to be dry after storage in the ocean at an elevation of -35 feet for 35 years. This type of pile has been used in the Los Angeles harbor since 1925 with no symptoms of deterioration to date.

Shotcrete, also known as gunite or spraycrete, is another form of concreting which has been used with success in the marine environment. It is

usually proportioned by volume in the ratio of one part cement to four parts well graded sand although richer mixtures have been used. The richer mixtures have an increased tendency to cracking as a result of temperature variations and alternate wetting and drying. Twenty-eight day compressive strengths of 4000 psi are possible with the leaner mixtures, well within the requirements of most design structures. The use of shotcrete instead of conventionally placed concrete can result in savings of material and time, as well as providing a more uniform and dependable member if the field control of the conventional formwork pouring is limited or inadequate. It has very good bending characteristics with older concrete and is, therefore, used for patching and plugging of existing structures. The critical parameter in the success of a shotcreted member is the skill of the craftsman applying the shotcrete. The angle of the nozzle, the rate of application, the amount of pressure on the line, the distance of the nozzle from the member, all are critical to the success of the structure. The final design decision to use conventionally placed concrete or shotcrete can be made on the basis of economy since the deterioration rates are quite similar. One disadvantage of the shotcrete method is that it cannot be used to produce a massive member.

CHAPTER IV

DESIGN PARAMETERS

The function of bridge fendering systems is to protect bridge elements against damage from waterborne traffic. There are many factors to be considered in the design of fendering systems including the size, contours, speed, and direction of approach of the ships using the facility, the wind and tidal current conditions expected during the ship's maneuvers and while tied up to the berth, and the rigidity and energy absorbing characteristics of the fendering system and ship. The final design selected for the fender system will generally evolve after making arbitrary limitations to the values of some of these factors and after reviewing the relative costs of initial construction of the fendering system versus the cost of fender maintenance and ship repair. It will be necessary to decide upon the most severe docking or approach conditions to protect agginst and design accordingly; hence, any situation which imposes conditions more critical than the established maximum would be considered in the realm of accidents and probably result in damage to the dock, fendering system, or ship.

The kinetic impact energy may be simply expressed as;

$$E = \frac{1}{2} mv^2 \tag{1}$$

where E is the energy of the system of mass, m, moving at a velocity, v. Each of these variables involves a complicated set of interrelationships bearing directly on the design of an adequate fendering system.

The total energy, E, may be expressed as the sum of many component energies: E_{f-d}, the energy absorbed by the fender and dock structure, E_s,

the energy absorbed by the ship, and E_{Lost}, the energy lost due to friction
with the harbor bottom, friction in the fender-dock system, etc. While the
energy lost in unexpected forms may cause problems requiring dredging and
other physical modifications, it cannot be accurately evaluated due to its
random nature.

Energy absorption in the ship may occur in two basic ways: by deforma-
tion of the hull, E_d, or by rebound of the ship, E_m. For the purposes of
simplification, deformation will be assumed to occur in the elastic regime.
The energy of the ship can, therefore, be expressed as;

$$E_s = E_d + E_m \qquad (2)$$

E_m is the function of the radius of gyration of the vessel, the vessel geome-
try, sea conditions, and the velocity and deceleration of the vessel immed-
iately prior to impact. Accurate analytical determination of E_m is impossi-
ble. It is, therefore, necessary to evaluate the importance of this energy
to the system, and, if possible, justify its elimination from consideration.

The transfer of energy to the fender at the moment of impact results in
deflection of the fender. At some small increment of time immediately after
this, some energy is transferred back to the vessel in the form of the energy
of rebound. The rebound energy is a function of the stiffness of the fender
which determines the characteristics of the collision as well as the deflec-
tion of the fender under various loading conditions. The result of this re-
bound is translation and rotation of the vessel in three dimensions causing
pitch, yaw, and roll. Maximum rebound energy requires the collision to be
completely elastic resulting in no energy absorption by the fender. If this
were the case, severe damage might be incurred by the vessel due to the lim-
ited stress-strain characteristics of any finite material element. Minimum
rebound energy would occur for a totally inelastic collision where all energy

is absorbed by the fendering system. A system designed for minimum energy case with a finite deflection range would tend to be stiff resulting in possible damage to the vessel. Between these two extremes lie the actual case. Conservative design measures call for no rebound by the ship or an assumption of the ratio of the rebound energy to the hull deformation energy. If E_{Lost} is assumed to be negligible, the total energy equation reduces to;

$$E = E_d + E_{f-d} \tag{3}$$

The impact energy is a time related function of impulse. The effects of impact on a ship hull may be divided into three time increments and examined separately. During the period of localized effect, between 0 and 1/200 second, stress and deformation characteristics are determined by the dynamic elasticity of plate panels, frames, stringers, girdles, etc. The resulting three dimensional equations can be solved only for very simplified, idealized structures with results of questionable value for the actual physical situation. During the transition period, from 1/200 to 1/20 second, a stress-deformation wave travels through the ship. After 1/20 second a vibratory motion is established. Damping of these oscillations results from internal friction in the steel hull, fluid friction in the boundary layer adjacent to the ship, wave or ripple formation on the ocean surface, and friction and slip in the lab and butt-riveted joints of the hull. These factors have been evaluated both experimentally and analytically assuming a simple beam structure. Experimental results yield decremental damping time functions three to ten times those obtained by simple beam assumptions.

Research into the area of the impact response is needed to shed light on the complex behavior of the ship. Several expressions which could be used to develop scale models for research include equations for velocity of the shear-bending wave in the hull, V_{s-b}, the frequency, v, and the impact load ($F(t)$:

86

$$V_{s-b} = \sqrt{G_g/\rho_H} \qquad (4)$$

where V_{s-b} is the velocity of the shear-bending wave in the hull, G is the shear modulus of elasticity, g is the acceleration of gravity, ρ_H is the density of the hull material;

$$\omega = \sqrt{EI_g/\rho_H A_H L^4} \qquad (5)$$

where ω is the frequency, E is the modulus of elasticity, I is the moment of inertia of a cross section about the neutral axis, g is the acceleration of gravity, ρ_H is the density of the hull material, A_H is the cross-sectional area of the hull, L is the length of the hull;

$$P(t) = \rho_{f-d} V^3 t L_s \qquad (6)$$

where P(t) is the impact load, ρ_{f-d} is the equivalent fender-dock material density, V is the velocity of impact, t is the time measured as t=0 at impact, L_s is the length of the hull in contact with the fender.

The energy absorbed by the fender is a function of the stiffness of the fender and the impact energy. If the stiffness of the fender is expressed by the value k and the deflection by d, the energy absorbed by the fender, E_f, is;

$$E_f = kd^2 \qquad (7)$$

Complications arise from the fact that k is generally not a constant but a function of deflection. Appendix I contains the graphs of k vs. d curves. The Appendix also contains energy tables listing energy levels as a function of the percent deflection based on the initial size of the fendering device. The Appendix is grouped by companies for easy reference. The data used to generate the curves and tables was taken from design aids published by the manufacturers.

The evaluation of the energy absorbed by the dock or pier structure

87

introduces further complexities to the system. The structural components
have varying stiffnesses, deflection limits, geometric shapes, external
operating parameters, etc. As the sophistication of the structure increases,
so do the number and complexity of the energy equations. Various simplifying
assumptions have been proposed. The most popular to date consists of replacing
the structural members with springs and rigid plates with non-linear functions
incorporated in the spring constant expressions. This method lends itself to
computerization and allows complete analysis of the entire system once a
spring-rigid plate model is developed and spring constants are determined.
In this manner the energy absorbed by the structure can be expressed in terms
of various stiffnesses and deflections dependent upon the impact energy of
the vessel and the fraction of the energy which might be absorbed by the
ship. In this analysis also, the difficulty of evaluating the proportion-
ality of the energy absorption of the ship and structure again becomes
evident.

The need to determine this proportionality has led to the use of many
equations of the form;

$$E_f = C \times E \qquad\qquad (8)$$

where E_f is the energy abosrbed by the fender, C is some constant which re-
flects the amount of energy which is not absorbed by the ship or pier struc-
ture and must, therefore, be absorbed by the fender, and E is the kinetic
energy of impact. The constant, C, is a function of the berthing point of
the ship, the geometry of the ship, the hull stiffness, the type of dock
structure, the sea exposure conditions, and the hydrodynamic mass, or the
added mass of water set in motion by the ship.

The components of the energy constant, C, can be grouped into various
coefficients; an eccentricity, C_E, a stiffness coefficient, C_S, a configura-

tion coefficient, C_C, and a hydrodynamic coefficient, C_H. C is as follows:

$$C = C_E C_S C_C C_H \qquad (9)$$

The eccentricity coefficient, C_E, adjusts the impact vector, which is generally not along the velocity vector, to that portion which is normal to the pier. The rest of the energy is utilized as rotational energy. If the assumption is made that the geometric center of the vessel is also the center of gravity, an expression can be written which relates the radius of gyration of the ship about the vertical axis through the center of gravity, K, with the distance along a line joining the center of gravity and the point of impact, r, and the angle between r and the velocity vector, ϕ;

$$C_E = \frac{K^2 + r^2 \cos^2\phi}{K^2 + r^2} \qquad (10)$$

Figure 49 is a schematic diagram of this non-sliding contact of the ship and the fender. r is the line joining the center of mass with the impact point; V is the velocity vector; ϕ is the angle between r and V and C.G. labels the center of geometry. This may differ from the center of gravity due to the loading condition of the ship. An exact calculation of the center of gravity would require detailed knowledge of the loading conditions and cargo of the shipping traffic, as well as extensive knowledge o' the architecture of the ship. To determine the center of geometry a plan view of a representative ship is required. From this view the center of gravity can be located and the analytical solution of equation 10 is possible.

An approximate solution can be obtained if the velocity vector, V, is assumed to act perpendicular to the line joining the center of gravity and the impact point: $\phi = 90°$. Equation 10 then becomes:
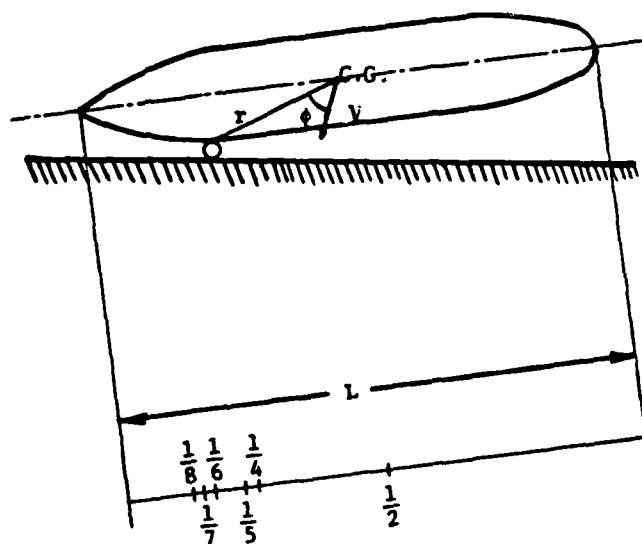
FIG. 49: Schematic Diagram of Ship Contact

$$C_E = \frac{K^2}{K^2 + r^2} \tag{11}$$

or

$$C_E = \frac{1}{1 + (r/K)^2} \tag{12}$$

Figure 50 is generated by solving equation 12 for various berthing points measured as a function of the ship length, L, as illustrated in Figure 49. Commonly used values are: for impact at a third point (1/3 the length of the ship), $C_E = 0.5$, and for impact at a quarter point (1/4 the length of the ship), $C_E = 0.7$, from Figure 50.

The configuration coefficient, C_C, is a function of the supporting structure and is generally assumed equal to 1.0 for an open pier, 0.9 for a semi-closed pier and 0.8 for a closed pier. The open and closed configurations are illustrated in Figure 51.

The stiffness coefficient, C_S, is generally assumed to be 0.9 as a conservative estimate of the percentage of energy which the fender must absorb based solely on stiffness relationships.

The hydrodynamic mass concept attempts to account for the added forces, pressures, and impulses that arise from the motion of a ship through some body of water. This added mass of water is considered to be added to the mass of the ship and said to govern the motion of the ship. This type of approach has been used to account for those factors not covered by the other parameters. The effect of consideration of the added mass depends on many factors: waves, winds, nature of impact, character of the structure, flow of water around the ship and structure, etc. A demonstration of the variability of this factor requires only a brief look at the berthing man-euvers of a ship approaching the dock at two speeds. In the first case, the
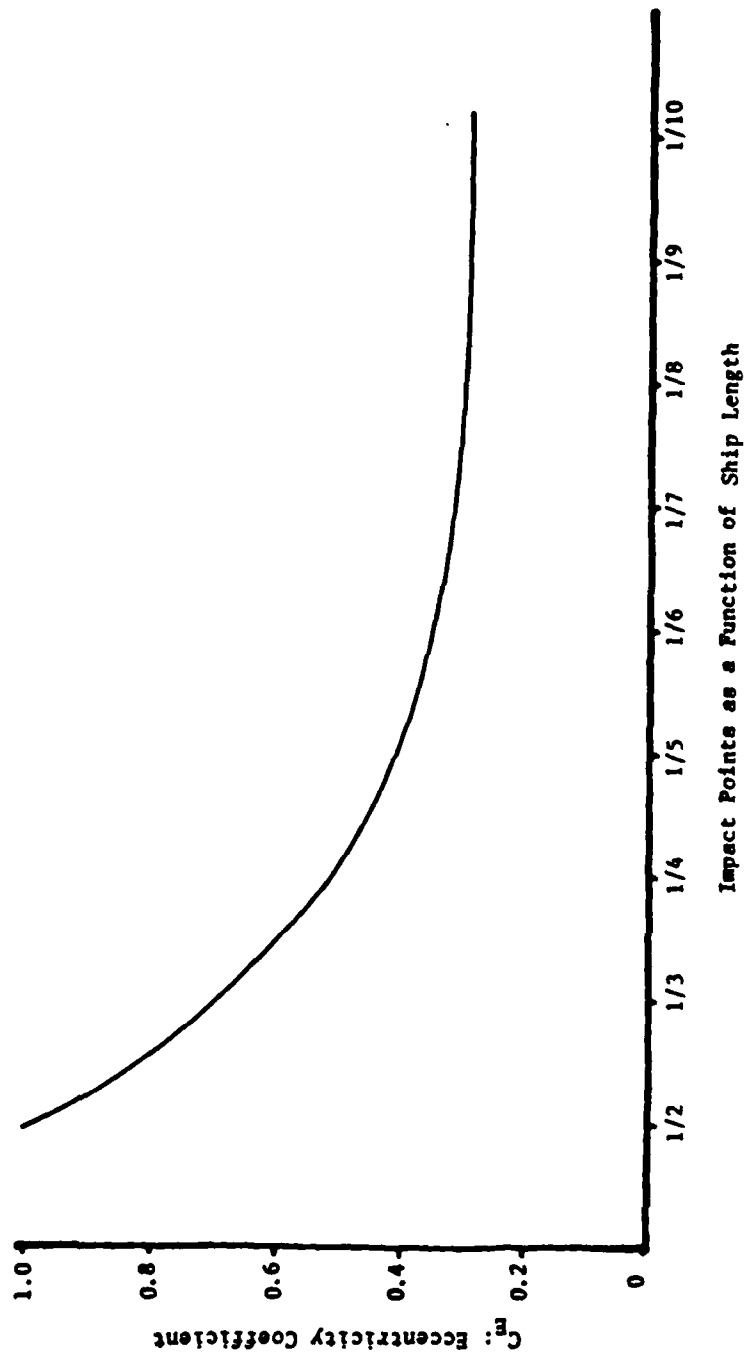
FIG. 50: Eccentricity Coefficient vs. Impact Points

Impact Points as a Function of Ship Length

92
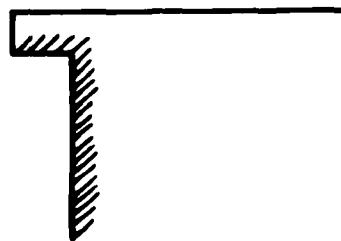
51a   Closed dock structure or
pier structure
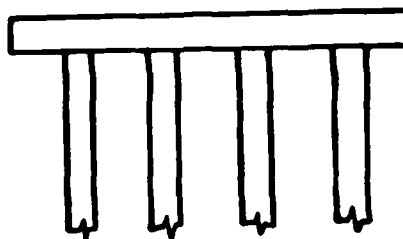
52b   Open dock structure or
pier structure

FIG. 51: Open and Closed Dock and Pier Structures for
the Determination of the Configuration Coefficient

approach is rapid and braking of the forward motion occurs suddenly. The
water is forced to flow around the vessel resulting in some forward motion
and impact force due to the mass of water. In the second case, the velocity
is low and braking occurs gradually. The mass of water does not split to
flow around the vessel and the effects of the moving water body are almost
negligible.

Past design techniques have described this added water mass, M_W, as
a cylinder whose diameter is the draft of the ship, D, and whose length is
the length of the ship, L.

$$M_W = \pi/4 \; D^2 L \rho_W \tag{13}$$

where ρ_W is the density of the water and may vary with geographic
location. The hydrodynamic coefficient in this analysis is the ratio of
the added water mass to the displaced mass of the ship, M_S:

$$C_H = M_W/M_S \tag{14}$$

The ratio of M_W to M_S, or C_H, has been correlated to the ratio of the beam
of the ship, B, to the draft of the ship, D, and is shown in Figure 52a.

Other design methods involve the use of empirical equations relating
C_H to B/D. The most commonly used is

$$C_H = 1 + 2 \; D/B \tag{15}$$

The second term in this expression, 2D/B, is shown in Figure 52b and is
labelled to 2 D/B. Adding 1.0 to the value read from this graph gives the
C_H value for design. Another suggested equation is

$$C_H = 0.3 + 1.8 \; D/B \tag{16}$$

This equation is shown in Figure 52b and is labeled 0.3 + 1.8 D/B.
The value read directly from this graph is the C_H design value.

Figures 52a and 52b allow quick visual determination of C_H values when

51.a: D/B: Draft/Beam

Hydrodynamic Coefficient
$C_H = M_H/M_S$

51. b: D/B: Draft/Beam

Hydrodynamic Coefficient
C_H

0.3 + 1.8 D/B

2D/B
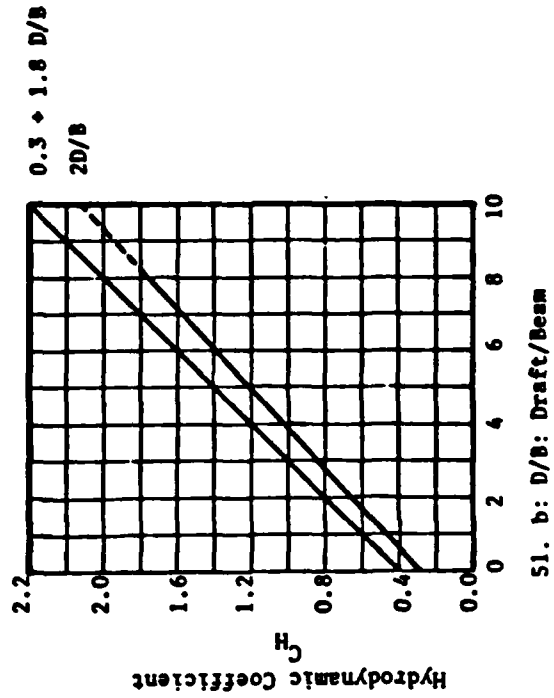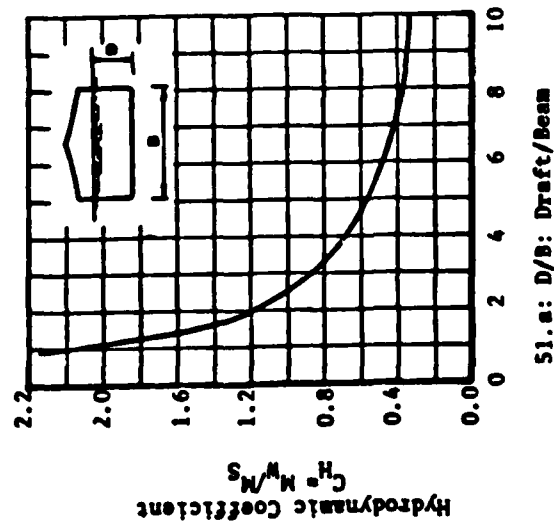
FIG. 52: Hydrodynamic Coefficient vs. Draft to Beam Ratios

these values are to be incorporated in design considerations. All of these approaches for the determination of C_B are approximations and differ from measurements using scale models and actual berthing maneuvers. Model studies and berthing maneuvers yield coefficient values ranging from 1.3 to 3.0.

Values presented by various companies in their design aids range from 1.5 to 1.9 as compared with the model-berthing values and the approximate values from equations 14, 15 or 16. Further research into this area is indicated although the variability of the impact velocity and slowing rate may be controlled by human judgment and experience.

The velocity of impact of vessels has received much study in the past few years. It is affected by currents, wind acting on the freeboard area, boundary layer conditions, and pilot experience. It appears that while smooth curves may be forced through data points relating velocity to other factors, the single largest factor governing the impact velocity is the nautical judgment of the pilot during berthing or passing maneuvers. While some authors have suggested an inverse relationship between size and speed, practical experience has shown that reductions in the design velocity based on this assumption may result in overloading the designed structure during the normal range of operations. The following values have been suggested as design velocities by some of the companies surveyed. The velocities are expressed in units of feet per second (fps).

| | | SHIP DISPLACEMENT | | |
Wind and Swell	Approach Conditions	Up to 3,000 tons	Up to 10,000 tons	Over 10,000 tons
Strong	Difficult	2.5	2.0	1.5
Strong	Favorable	2.0	1.5	1.0
Moderate	Difficult	1.0	0.8	0.6

Actual conditions should determine what value is used for design. Future studies of the impact velocity might hinge on the human factors involved as well as quantifying the velocity relationships.

96

The energy equation has often been presented in the form:

$$E_f = 1/2 \ E$$

This indicates that the C value equals 1/2. If the individual factors are studied under common conditions, a slightly higher general value of C in indicated.

Case 1.

$$C = C_E \ C_S \ C_C \ C_H \qquad (9)$$

$C_E = 0.38$ (Impact at sixth point)
$C_S = 0.90$ (General stiffness)
$C_C = 0.80$ (Closed pier structure)
$C_H = 2.00$ (B = 2D)

$$C = 0.46$$

Case 2.

$$C = C_E \ C_S \ C_C \ C_H \qquad (9)$$

$C_E = 0.50$ (Impact at quarter point)
$C_S = 0.90$ (General stiffness)
$C_C = 1.0$ (Open structure)
$C_H = 2.0$ (B = 2D)

$$C = 0.90$$

For general use a value of C = 0.68 is recommended. This value is the average of the two cases illustrated above and appears more reasonable for design than the arbitrary assumption of C = 0.50. For most cases, however, evaluation of each coefficient factor is recommended.

The firm of Ewin, Campbell, and Gottlieb of Mobile, Alabama has provided us with four details of a fender study they did for the Alabama State Dock Department for berth numbers 3, 4, 5, 6, 7, and 8. These details appear on the next page.

97
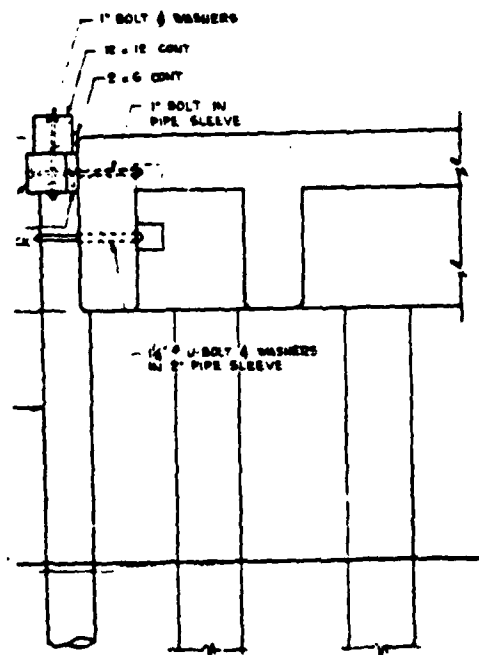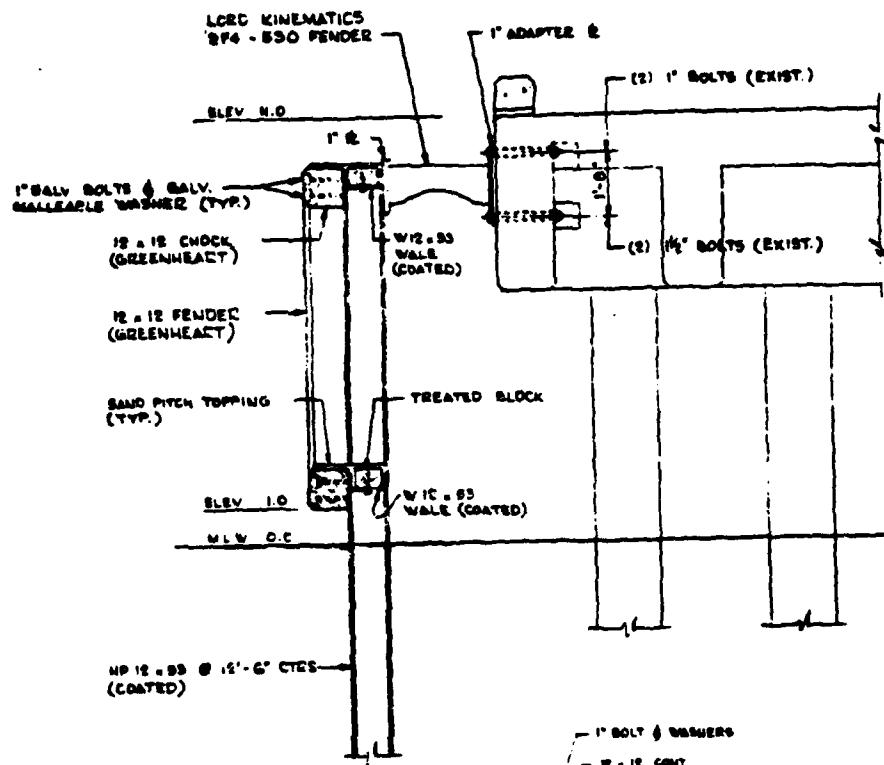
Various Schemes for Berth Conditions
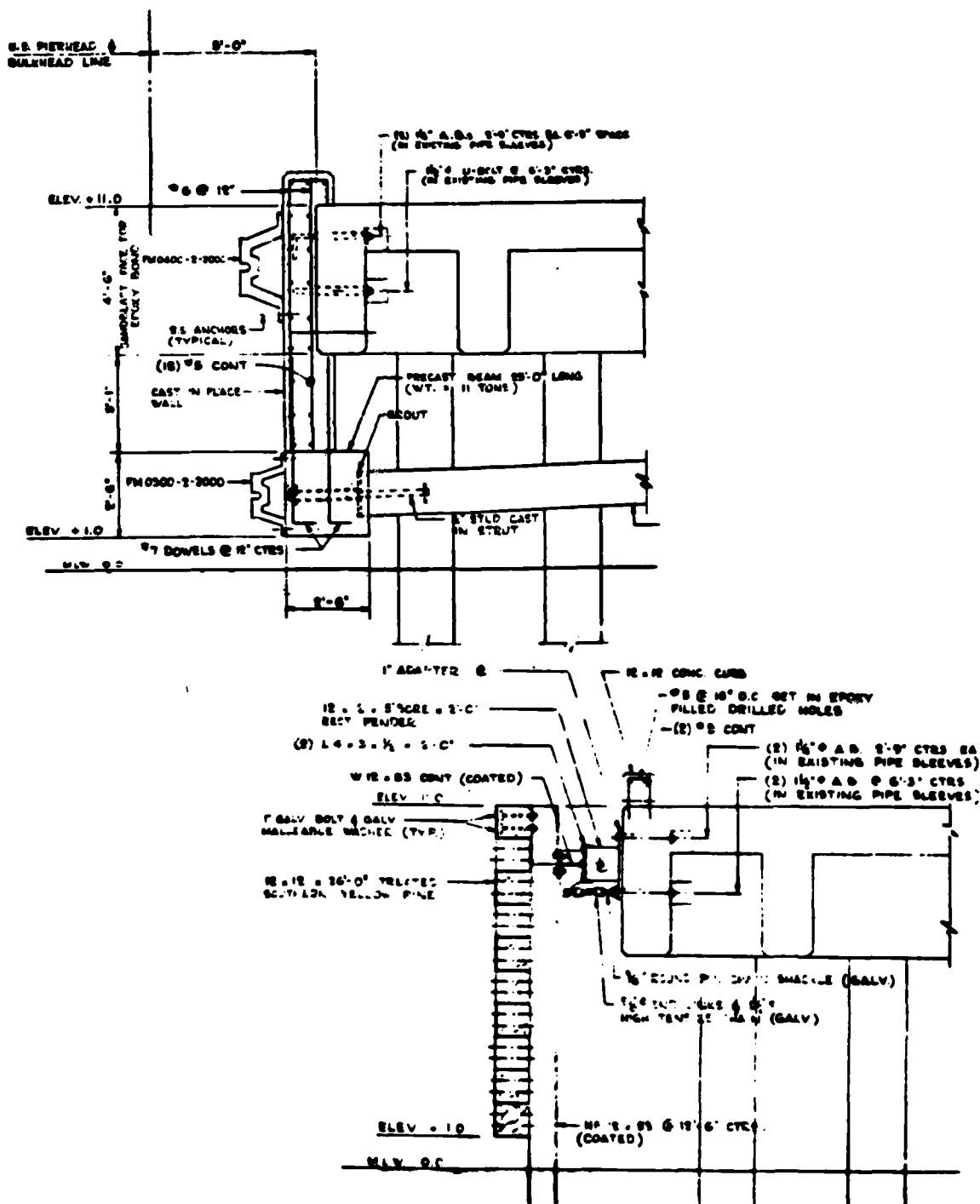
Various Schemes for Berth Conditions

CHAPTER V

HAND COMPUTATIONS

INTRODUCTION

This chapter contains several examples of simplified fender designs based on the design procedures and assumptions discussed previously. Each problem is presented in a step-by-step fashion with a range of solutions presented where applicable. It is noted that many facilities to which fenders are applied consist of pile groups. Where these piles act as a group, the design steps presented do not account for the distribution of the energy absorbed among the individual piles. Finally, the "factor of safety" concept may be applied to the solution of fendering requirements though the most desirable design method would involve solving the system for various conditions and selecting an appropriate design based on the results. Seven examples will be shown, namely;

1. A Timber Framework System
2. A Draped Rubber Fender
3. A Raykin Fender
4. A Pneumatic and Foam Filled Fender
5. A Lord Flexible
6. A Gravity Fender
7. A Steel Spring

EXAMPLE NO. 1: A TIMBER FRAMEWORK SYSTEM

Design a timber framework system for the given conditions:

1. A concrete pier with partially closed supporting structure.

100

2. With the shipping traffic consisting primarily of bulk ore carriers with average values of:

Length	= 740'
Breadth	= 101'
Depth	= 56'
Draft (Loaded)	= 38.5'
Dead Weight	= 50,000 long tons
Displacement	= 62,500 long tons

3. With an angle of approach $\approx 10°$ and the velocity ≈ 0.25 feet per second.

Solution:

I. Evaluate the coefficients.

   a) Assume impact at quarter point $C_E = 0.5$

   b) Partially open structure $C_C = 0.9$

   c) Assume stiffness ratio $C_S = 0.9$

   d) Assume the hydrodynamic coefficient which can be expressed by the following equation:

   $$C_H = 1 + 2D/B = 1 + 2(38.5')/101' = 1.76$$

   e) Solve for $C = C_E \cdot C_C \cdot C_S \cdot C_H = 0.71$

II. Determine the collision or berthing velocity.

   $$V = 0.25 \text{ fps (cos } 10°) = 0.2462 \text{ fps}$$

III. Determine the energy which must be absorbed by the fendering system.

   $$E = C \frac{W}{2g} \cdot V^2 = 0.71 (\frac{62,500 \times 2240}{2 \times 32.2}) (0.246)^2$$

   $$E = 93,900 \text{ ft. lbs.}$$

IV. Wale Design:

   a) Assume the ship contacts two (2) fender piles.

101

b) Assume a wale size of 10" x 12" supported on 4" blocks, 10" on center.

c) Assume the amount of compression to equal 1/20 of the thickness.

$$d_1 = (1/20)(12" + 12") = 1.2"$$

d) Compute the amount of bending at the quarter points.

$$d_2 = \frac{Pa}{6EI}[\frac{3l^2}{4} - 4a^2]$$

where:

   l = Length on center = 12" x 10' = 120 in.

   a = 1/4 = 120/4 = 30"

   E^* = Young's Modulus for given material

   I = Moment of inertia ($bh^\#/12$) = 1440 in.^{4}

   * = The material properties for a given species of wood may be found by contacting the National Forest Products Association or consulting the Forest Products Manual.

If it is assumed that the waler is to be made of

Douglas fir, the following properties would apply:

   $E = 1.90 \times 10^6$ psi

   Impact bending = 4800 psi

   Impact compression = 1000 psi

$$d_2 = \frac{P(30")}{6(1.9 \times 10^6)(1440 \text{ in.}^4)} [\frac{3(120")^2}{4} - 4(30")^2]$$

$$d_2 = 1.32 \times 10^{-5} P$$

e) Then equate the energy used in bending and compression to that absorbed by the fendering system.

$$2P(d_1 + d_2) = C\frac{W}{2g} V^2$$

$$2P(1.32 \times 10^{-5}P + 1.2) = 93,900 \text{ ft. lbs.}$$

$$P = 29,530 \text{ lbs.}$$

f) Compute the compression and bending stresses to insure
that they are within the minimum values.

$$\text{Compression stress} = \frac{P}{\text{Bearing Area}}$$

Assume a 5" width of contact between fender pile and water:

$$\text{Compression} = \frac{29,530}{5" \times 12"} = 492 \text{ psi} < 1000 \text{ psi} \quad \text{O.K.}$$

$$\text{Bending} = M_c/I = P_{ac}/I = \frac{29,530(30)(5)}{1440} = 3076 \text{ psi} < 4800 \text{ psi}$$

$$\text{O.K.}$$

EXAMPLE NO. 2: A DRAPED RUBBER FENDER

Design a Draped Rubber Fender utilizing the same parameters as in Example
No. 1.

Solution:

    I. Evaluate the coefficients.

$$C = 0.71$$

    II. Determine collision velocity.

$$V = 0.2462 \text{ fps.}$$

    III. Determine energy absorbed by fendering system.

$$E = 93,900 \text{ ft. lbs.}$$

Assume contact surface = 2 feet.

$$E/\text{contact} = 46,950 \text{ ft. lbs./ft.}$$

103

IV. Find appropriate fendering system from energy tables located in the Appendix using;

$$E = 93.9 \text{ K-ft. or } 1126.8 \text{ K-in.}$$

and

$$E/ft. = 46.95 \frac{\text{K-ft.}}{ft.} = 563.4 \frac{\text{K-in.}}{ft.}$$

The following are some fendering possibilities.

| | | Energy at Percent Deflection | | | | | |
Company	Fender Name	50	60	70	80	90	100
	Goliath (K-in.)						
	1000 x 500 (K-in.)				1130	1433	2000
	1200 x 600 (K-in.)			1303	1738	2170	2610
	1400 x 800 (K-in.)			950	1390	2000	3475
	1500 x 800 (K-in.)			1000	1564	2260	3475
Goodyear	None Available						
Uniroyal	60" Cylindrical ($\frac{\text{K-in.}}{ft.}$)					630	828

Any of the above fendering systems may be used. The choice among them may be based on economy, hull pressure, or installation requirements.

The computation of the hull pressure is as follows:

a) Assume a fender size: 1000 x 500

b) Determine the amount of deflection for given energy.

Since we need D = 1126.8 K-in. and at 80 percent deflection we have 1130 K-in., we are within the range. Therefore, from the energy table Δ_{max} = 20.5" and the deflection = 20.5" x 0.80 = 16.4".

c) Determine the stiffness coefficient from the appropriate curve.

At a 16.4" deflection, K = 8.5 Kips per inch

d) Determine the reaction force.

$$F = K \times \Delta = (8.5)(16.4) = 139.4 \text{ Kips}$$

e) Determine surface area of contact.

Assume approximately 1 sq. ft. or 144 sq. in.

f) Determine hull pressure.

$$\text{Pressure} = 139.4 \text{ K}/144 \text{ in.}^2 = 0.97 \text{ Kips/in.}^2$$

g) Check this against ships' specifications and it it checks, then we use the assumed fendering system.

EXAMPLE NO. 3: THE RAYKIN FENDER

Design a Raykin Rubber Fender given the same design parameters as in the previous two examples.

Solution:

Since this is a rubber fender design, the same procedure and calculations apply as in Example No. 2, and we go directly to the Raykin tables to choose our system.

The following Raykin fenders are available for the mathematics of Example No. 2.

Company	Size	Energy at Percent Deflection				Δ_{max}
		70	80	90	100	
General Tire and Rubber, Raykin	E-40 tons			950	1180	18.8 in.
	-45 tons			1080	1330	18.8
	-50 tons		936	1200	1520	18.8
	-60 tons		1074	1380	1740	18.8
	F-40 tons			1100	1332	22.4
	-45 tons		1010	1248	1500	22.4
	-50 tons		1120	1380	1632	22.4
	-60 tons	1020	1320	1660	2040	22.4

Hull pressure is tabulated for a bearing area of 2 sq. ft. or 288 sq. in. The procedure and results are tabulated below.

Size	Percent Deflection for E = 1126.8 K-in.	Deflection (Δ, in.)	K (K/in.)	Reaction Force (K x Δ, K)	Pressure (psi)
E-40 tons	97.8	18.4	6.2	114.1	396
-45 tons	92.0	17.3	7.0	121.1	420
-50 tons	87.3	16.4	8.8	144.3	500
-60 tons	81.8	15.4	9.4	144.8	503
F-40 tons	91.3	20.5	4.7	96.4	335
-45 tons	85.0	19.0	5.4	102.6	356
-50 tons	80.4	18.0	6.0	108.0	375
-60 tons	73.7	16.5	7.5	123.0	430

These pressures are all within the allowable limits for most cargo ships. The choice among them may be based on economics.

EXAMPLE NO. 4: PNEUMATIC AND FOAM FILLED FENDERS

Design a pneumatic or foam filled fender given the following conditions:

1. A concrete pier with a completely closed structure.

2. With the shipping traffic consisting primarily of tankers with average values of:

    Length   = 1130'

    Breadth   = 110'

    Draft   = 65'

    Dead Weight   = 330,000 long tons

    Displacement = 380,000 long tons

3. With an angle of approach 20° and the velocity 0.25 feet per second.

Solution:

I. Evaluate coefficients.

   a) Assume impact at quarter point, therefore, C_E = 0.5

   b) Closed structure, therefore, C_C = 0.8

   c) Assume stiffness ratio, therefore, C_S = 0.9

   d) Assume the hydrodynamic coefficient which can be expressed by the following equation:

$$C_H = 1 + 2D/B = 1 + 2(65')/110' = 2.17$$

   e) Solve for $C = C_E \cdot C_C \cdot C_S \cdot C_H = 0.78$

II. Determine the collision or berthing velocity.

$$V = 0.25 \text{ fps } (\cos 20°) = 0.235 \text{ fps}$$

III. Determine the energy which must be absorbed by fendering system.

$$E = C \cdot \frac{W}{2g} \cdot V^2 = \frac{0.78(380,000 \times 2240)(0.235)^2}{2 \cdot 322}$$

107

$$E = 569,350 \text{ ft. lbs.}$$

$$E = 6830 \text{ K-in.}$$

The following are some fender possibilities:

Company	Fender Name	Energy of Percent Deflection					Δ_{max}
		30	40	50	60	70	
Yokohama	Pneumatic						
	2500 x 5500			3,900	6,900		
	3300 x 6500		4,560	8,940			
	4500 x 9000	5,400	12,000	23,750	42,300		177.2
Seward	Foam Filled						
	8 x 16				6,000	9,300	96
	10 x 16		3,600	6,900	9,240		120
	10 x 20		4,500	7,500	11,400	18,000	120
	11 x 22		6,000	9,900	15,300	24,000	132
Sampson	Sprayed						
	8 x 16			4,200	7,320		96
	8 x 20			5,100	9,480		96
	10 x 16			6,600	11,500		120
	10 x 20		4,320	7,200	13,200		120

Any of the above fendering systems filfills the energy requirements. The choice among them may be based on economy, hull pressure, or installation requirements.

The computation of the hull pressure will compare one of each of the above types of fenders. The table below shows the significant values for energy absorption of 6830 K-in. K values are taken from the appropriate curves.

Company	Fender Name	Percent Deflection for 6830 K-in.	Deflection (in.)	K (K/in.)	Reaction Force (K)
Yokohama	Pneumatic				
	3300 x 6500	45.2	58.7	7.2	422.6
Seward	Foam Filled				
	10 x 16	50.0	60.0	3.8	228.0
Sampson	Sprayed				
	10 x 20	48.7	58.4	6.0	350.4

The Seward fender yields the lowest reaction force for this example and would, therefore, be the first choice if hull pressure is a significant design requirement. The bearing area to be used in the calculation is dependent upon the contours of the ship traffic.

EXAMPLE NO. 5: LORD FLEXIBLE FENDER

Design a Lord flexible fender for the given situation:

1. A concrete pier with an open structure.

2. With the shipping traffic consisting of passenger ships with average values of:

Length	= 920'
Breadth	= 105'
Draft	= 32'
Depth	= 45'
Dead Weight	= 10,500 long tons
Displacement	= 27,000 long tons

3. With an angle of approach   15° and the velocity   0.25 feet per second.

Solution:

I. Evaluate coefficients

a) Assume impact at sixth point $C_E = 0.38$

b) Open structure $C_C = 1.0$

c) Assume stiffness ratio $C_S = 0.9$

d) Assume the hydrodynamic coefficient which can be expressed by the following equation:

$$C_H = 1 + 2D/B = 1 + 2(32')/105' = 1.61$$

e) Solve for $C = C_E \cdot C_C \cdot C_S \cdot C_H = 0.55$

II. Determine the collision or berthing velocity.

$$V = 0.20 \text{ fps } (\cos 15°) = 0.193 \text{ fps}$$

III. Determine the energy which must be absorbed by fendering system:

$$E = C \cdot \frac{W}{2g} \cdot V^2 = \frac{0.55(27,000 \times 2240)(0.193)^2}{2 \cdot 32.2}$$

$$E = 19,240 \text{ ft. lbs.}$$

$$E = 230.9 \text{ K-in.}$$

The following are some fender possibilities obtained from the Lord tables:

Company	Fender Name	Energy at Percent Deflection					Δ_{max}
		60	70	80	90	100	
Lord	2F4-212				228	264	14.5
	-319		215	275	325	390	14.5
	-390	230	275	350	410	460	14.5

The hull pressure is based on a bearing area of one square foot or 144 square inches. The K values are obtained from the appropriate curves.

Company	Fender Name	Percent Deflection	Deflection (in.)	K (K/in.)	Reaction Force	Pressure (psi)
Lord	2F4-212	90.6	13.1	1.75	22.9	159
	-319	72.5	10.5	3.05	32.0	222
	-390	60.0	8.7	4.10	35.7	250

The above pressures are within allowable limits for most passenger ships. The choice among them may be based on economics or installation limitations.

EXAMPLE NO. 6: GRAVITY FENDER

Design a gravity fender utilizing the same parameters as Example No. 5.

Solution:

I. Evaluate the coefficients.

$$C = 0.55$$

II. Determine the collision or berthing velocity.

$$V = 0.193 \text{ fps}$$

III. Determine energy absorbed by the fendering system.

$$E = 19,240 \text{ ft. lbs.}$$

$$E = 230.9 \text{ K-in.}$$

IV. Structural limitations restrict the amount of deflection to 24 inches.

The equation of the energy loss for the gravity fender is;

$$E = F \times d$$

where E is energy loss, F is the weight of the fender, and d is the horizontal

displacement. Rearranging the terms yields;

$$F = \frac{E}{d} = \frac{230.9 \text{ K-in.}}{24 \text{ in.}} = 9.6 \text{ Kips}$$

The structure must then be built to support this weight and allow the required displacement of the mass.

EXAMPLE NO. 7: STEEL SPRING FENDER

Design a steel spring fender utilizing the same parameters as Example No. 5.

Solution:

I. Evaluate the coefficients.

$$C = 0.55$$

II. Determine the collision or berthing velocity.

$$V = 0.193 \text{ fps}$$

III. Determine the energy absorbed by the fendering system.

$$E = 19,240 \text{ ft. lbs.}$$

$$E = 230.9 \text{ K-in.}$$

The equation of the energy loss for the steel spring is;

$$E = K \times d^2$$

where E is the energy loss, K is the spring constant, and d is the displacement along the length of the spring. Rearranging terms yields;

$$K = E/d^2$$

112

If structural limitations restrict displacement to ten inches, then;

$$K = \frac{E}{d^2} = \frac{230.9 \text{ K-in.}}{(10 \text{ in.})^2} = 2.309 \text{ K/in.}$$

The design of the spring to meet these requirements may follow any structural method.

CHAPTER VI

DESIGN APPLICATION AND COMPUTERS

INTRODUCTION

The design of fendering systems which protect bridge piers against ship impact or at minimum retard direct collision has utilized basic fundamentals of physics and simple pile equilibrium as illustrated in the previous two chapters. Such assumptions can often lead to grossly overdesigned systems or in some cases inaccurate force evaluation in the entire support system. Therefore, this chapter deals with the development of improved design criteria and the application of a complex computer oriented dynamic solution.

114

THEORY

General Techniques. – The general response of a piling system, when subjected to a ship, is computed by removing the pile and examining its effect as a cantilever beam, as shown in Figure 1. The interaction of lateral elements, such as walers are neglected and thus a conservative design. Two general theoretical equations are used by the designer, and are based on force-acceleration and kinetic energy relationships.

Force-Acceleration:

the induced or applied force to the system, caused by the ships impact is;

$$F_a = M(v_i^2 - v_f^2)/2\Delta_s \tag{1}$$

where: M = mass of ship

Δ_s = deformation of system at point of impact

v_i, v_f = initial and final velocity

the resisting force of the system is:

$$F_r = 3\Delta_s E(I/D.F.)/L^3 + \Sigma k\Delta_s \tag{2}$$

where: E = modulus of elasticity of pile

I = inertia of pile

$D.F.$ = lateral distribution of load due to lateral stiffness or effect

L = cantilever length of pile

k = spring constant of fendering

the induced moment and stress is computed from;

$$M = F_a \times L \text{ and} \tag{3}$$

$$f = M/(S/D.F.) \tag{4}$$

where: S = section modulus.

In applying this method the designer would assume on allowable Δ_s and initial stiffness I. If the resisting force $F_r > F_a$, then the actual Δ_s would be smaller than assumed. The induced stress f would be compared to the allowable or ultimate stress of the material.

Kinetic Energy:

The induced energy caused by the ship is given by:

$$E_{in} = \frac{1}{2} M v_i^2 (C_H)(C_s)(C_c)(C_E) \tag{5}$$

where: v_i = initial or translational ship velocity

C_H = hydrodynamic coefficient = $1 + \frac{2D}{B}$

D = draft of ship

B = beam of ship

C_E = eccentricity coefficient

C_s = softness coefficient

C_c = configuration coefficient

the C coefficients (C_E, C_s and C_c) can be set equal to 1.0, for the worst case. Other variations can be obtained for specific ship variables, as given in Ref. (2).

The output energy or that energy that can be absorbed by the piling system is;

$$E_o = F \cdot \Delta_p + \Sigma \frac{1}{2} k \Delta_f^2$$

but $\Delta_p = FL^3/3E(I/D.F.)$, therefore

$$E_o = F^2 L^3 / (3EI/D.F.) + \Sigma \frac{1}{2} k \Delta^2 \tag{6}$$

Using equations (5) and (6) and assuming $\Delta = FL^3/3EI/D.F.$ or zero, the induced force F is determined. The resulting Δ can then be evaluated and used to reevaluate E_o if $\Delta = 0$ was originally assumed. The resulting moment and stress is found as per equations (3) and (4).

System Technique. –

A complete pile system is shown in Figure 2, and includes the support piles and lateral walers, excluding fenders. This system in effect is a cantilever grid plate, subjected to a lateral load. The response of such a system has been determined by using a matrix formulation as represented by a finite difference scheme (3). The stiffness of this grid is defined as D_x and D_y, which is computed as $D_x = EI_x/\lambda y$ and $D_y = EI_y/\lambda x$.

Such a scheme, which has been computerized, has permitted direct solution of the deformations and forces throughout the pile grid system. Relationship between the induced system deformation and isolated pile gives a new design technque, classified herein as load distribution factor. This factor shows what percentage of load goes to each pile when the load is applied to one pile.

PARAMETRIC STUDY

In order to determine the distribution factor, is necessary to determine the system response. The determination of this factor (DF) has been obtained for typical grid stiffnesses (D_x, D_y) and span length (L) or height of the pile. A unit load effect was used in examining the system and single pile.

Longitudinal Stiffness. – D_y

The range in the stiffness $D_y = \dfrac{EI_y}{\lambda x}$, was determined by examination of typical steel HP, steel W, and 12 in. – 28 in. round timber members which are used in piling systems. The spacing λx was varied between 5 ft. and 25 ft., in 5 feet increments. The length of cantilever plate was varied between 20 ft. and 60 ft. in 4 feet increments.

<u>Transverse Stiffness.</u> - D_x

The range in the stiffness $D_x = \dfrac{EI_x}{\lambda y}$, was determined by also ex-
amining typical walers, which consisted of steel W and 10 in., 12 in.,
and 14 in. timber sections. The spacing λy was varied the same as
the λx variable.

<u>Range in Parameters.</u>

A study of all of the resulting stiffnesses indicates the follow-
ing ranges;

Variable	Lower Bond	Upper Bond
D_y	2×10^4 k-in.	6×10^5 k-in.
D_x	4×10^3 k-in.	10×10^4 k-in.
L	20 ft.	60 ft.

<u>Grid Difference Solutions</u>

Using these ranges in parameters and applying a unit load, the
maximum deformation in the system has been obtained. In all these
solutions a maximum of ten vertical mesh lines was used, where the
spacing of the lines was set equal to a constant $\lambda x = 60$ in., which
gave a width of 45 ft. The mesh points along these vertical lines was
fixed at $\lambda y = 48$ in. for the range of 20 ft. to 60 ft.

The solution of systems has given the Δsys which was then di-
vided by the factor $L^3/3EI_y$, which is called Distribution Factor (D.F.).
These results were then plotted, (D.F.) vs. pile height L, as given in
Figures 3 through 10. This ratio, given D.F., will now be described.

<u>Distribution Factor.</u>-

The finite difference cantilever grid equations can provide direct
deformation values along any pile. Depending on the lateral stiffness
(D_x), the deformation at the top of free edge of the piles can vary
dramatically. This variation is quite important if the designer wishes

118

to properly identify the interaction between the piles and an isolated pile. A convenient method to describe such interaction is to relate the deformation of the systems (Δs) to that of the isolated pile (Δp), which is called a distribution factor or:

$$D.F. = \frac{\Delta s}{\Delta p} \qquad (7)$$

where: Δs = maximum deformation in the grid system (finite differences)

$$\Delta p = PL^3/3EI_y - \text{cantilever pile deformation}$$

Equation (7) signifies the reduction in deformation of an isolated pile when that pile is part of the system and thus the influence of lateral stiffness. Therefore, the stiffness (I) of an isolated pile can be increased by the amount of $1/D.F.$ or I sys = $I_p/D.F.$ This factor has been referenced in equations (2) and (6).

The resulting distribution factors, for various relative stiffnesses, are given in Figures 3 through 10, and can be used for direct design.

119

COMPUTERIZED SOLUTION

As described previously, the system response can be evaluated by use of (D.F.) curves. This approach, although sufficient for engineering design, can be improved by utilization of structural dynamics and computerization. Such a system has been developed and incorporates the following features;

General.-

The interaction of a protective bridge fendering system, or wharfs which can consist of a series of piles imbedded in a soil medium and stiffened laterally, with possible absorbing devices attached, is a complex system under static conditions and highly redundant. This action is further complicated if the system is subjected to dynamic forces.

Another system which is utilized for bridge protection, is a cluster of piles wrapped with cables, or a cell dolphin or a series of steel piles with a rigid cap. The dynamic response of any of these systems is also complex.

In the past, the solution of either the fendering system or dolphin, has been examined by the engineer as a single element, fixed at the base (cantilever) and then applied as a basic physics relationship. This method rewards the engineer with simplicity but inherently may not be conservative nor safe. This condition has therefore led to the impetus of developing a computer oriented solution of such systems which can incorporate many variables, which are not possible in the simplified technique, and thus provide rapid and accurate solutions to a complex problem.

Assumptions.-

1. The piling interaction with the soil medium is considered, i.e., flexible supports.

2. Soil may be layered.

3. Piling group is considered as a three dimensional unit.

4. Interactions of the horizontal walers is considered.

5. Forces and deformations throughout all piles, at any time interval, can be evaluated.

6. The forces and deformations are evaluated along the length of each pile.

7. Rigid wharfs, fenders, dolphins, or combinations can be considered.

8. During ship impact, any pile that fails, is noted and the system is reevaluated.

9. Total energy in the system, input and output, is computed during each time interval.

10. The system may have any general plan orientation; i.e., (straight, curved etc.).

Input Data.-

The input requirements for the fendering or dolphin is flexible, depending on the problem. If the system is straight, then the spacing and point of impact need only to be specified. In the case of straight and curved systems, then the requirements are more rigorous. A sample of the various problems that can be investigated by the program are given in Sample Problems 1 through 10 for fendering system and Sample Problems 1 through 5 for dolphins,

121

FIGURE 1

FIGURE 2

122

DY = Constant = 2(10⁴)

DX = 4(10³)
DX = 8(10³)
DX = 2(10⁴)
DX = 6(10⁴)
DX = 10(10⁴)

L(ft.)

FIGURE 3

123

FIGURE 4

DY = Constant = $6(10^4)$

DX = $4(10^3)$
DX = $8(10^3)$
DX = $2(10^4)$
DX = $6(10^4)$
DX = $10(10^4)$

L(ft.)

FIGURE 5

125

DY = Constant = 8(10⁴)

DX = 4(10³)
DX = 8(10³)
DX = 2(10⁴)
DX = 6(10⁴)
DX = 10(10⁴)

L(ft.)

DF

FIGURE 6

126

FIGURE 7

127

FIGURE 8

128

FIGURE 9

129

FIGURE 10

130

1000 T.
1.4 knot

$F_y = 2 \text{ k/in}^2$

34'

50'

20.88"

$\mu = 1.6$

30°

6"

10 k

y

F

90"

20"

3   5   7   9   11 13 15 17 19   20

0   2   4   6   8   10 12 14 16 18   x

768 in^4

SAMPLE PROBLEM 1

131

10,000 T.

.4 knot

$F_y = 36$ k/in^2

$k = .04 \Delta^2 - .78\Delta + 10.4$

SAMPLE PROBLEMS 2, 8

132

10000 T.
.4 knot

$F_y = 2 \text{ k/in}^2$

$k = .02 \Delta^2 + 4$

34'

50'

20.88 20.88

327.529 in.

702.389 in.

3456 in^4

15°

60°

133

SAMPLE PROBLEM 3

1000 T.
.4 knot

$F_y = 2.0 \ k/in^2$

$k = .02 \ \Delta^2 - .39 \ \Delta + 5.7$

34'

50'

24"

20.88"

SAMPLE PROBLEMS 4, 9

134

1000 T
1.4 knot

$F_y = 2 \ k/in^2$

37'

34'

54'

50'

20.88"

90"

F

144 in.^{4}

1   3   5   7   9   11   13   15   17   19   21   22

20"

0   2   4   6   8   10   12   14   16   18   20

SAMPLE PROBLEM 5

135

Length = 120'

Cantilever Length = 20"₀
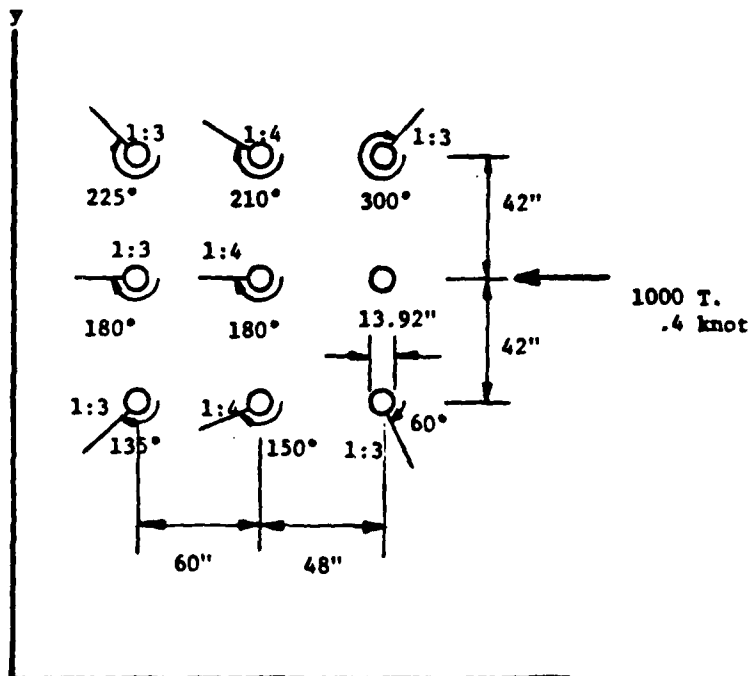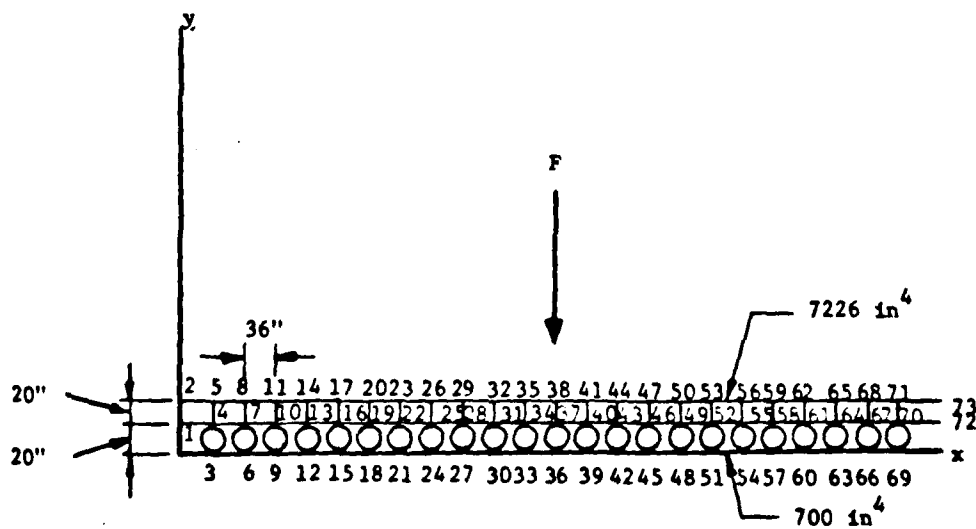
225°   210°   300°

1:3   1:4   1:3

42"

180°   180°   13.92"

1:3   1:4

1000 T.
.4 knot

42"

135°   150°   60°

1:3   1:4   1:3

60"   48"

$$k = .02 \, \Delta^2 + 3.99$$

F

36"

20"

20"

2 5 8 11 14 17 20 23 26 29 32 35 38 41 44 47 50 53 56 59 62 65 68 71
4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70
1

7226 in⁴

700 in⁴

3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60 63 66 69

73
72

SAMPLE PROBLEMS 6, 7

1.33 in.

6 ft.

F

48 ft.

65 ft.

SAMPLE PROBLEM 1

137

1 ft.

F

48 ft.

65 ft.

SAMPLE PROBLEM 2

138

1 ft.

48 ft.

65 ft.

F

SAMPLE PROBLEM 3

139

SAMPLE PROBLEM 4

140

SAMPLE PROBLEM 5

141
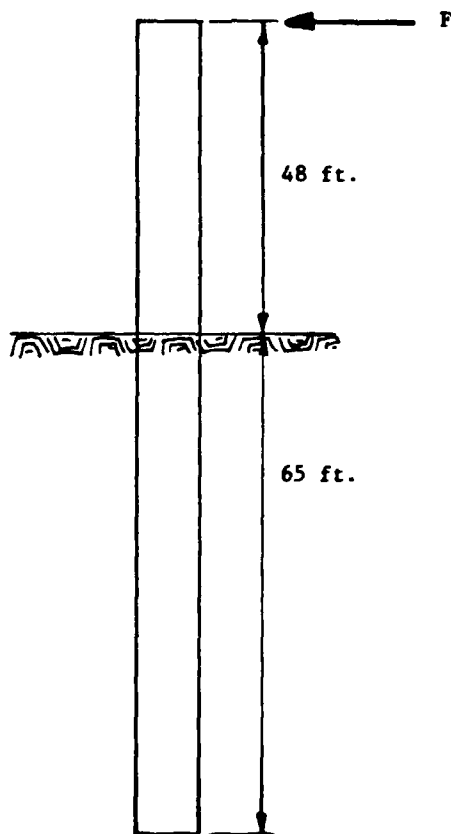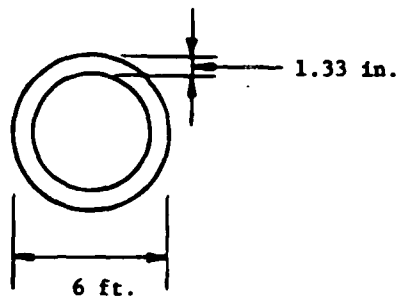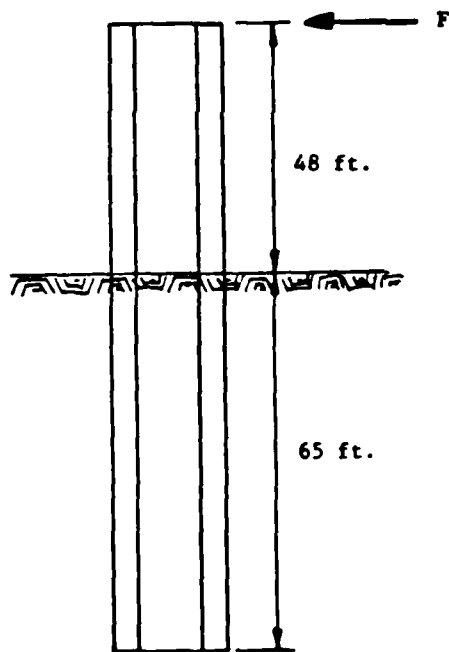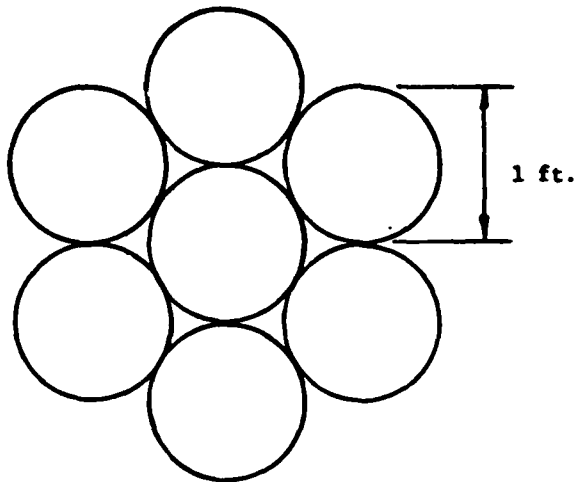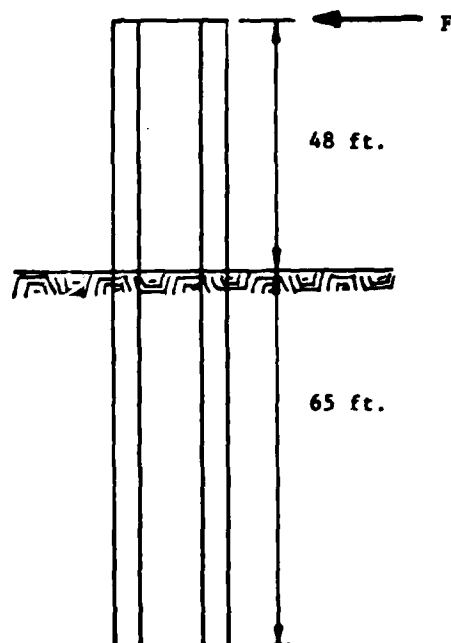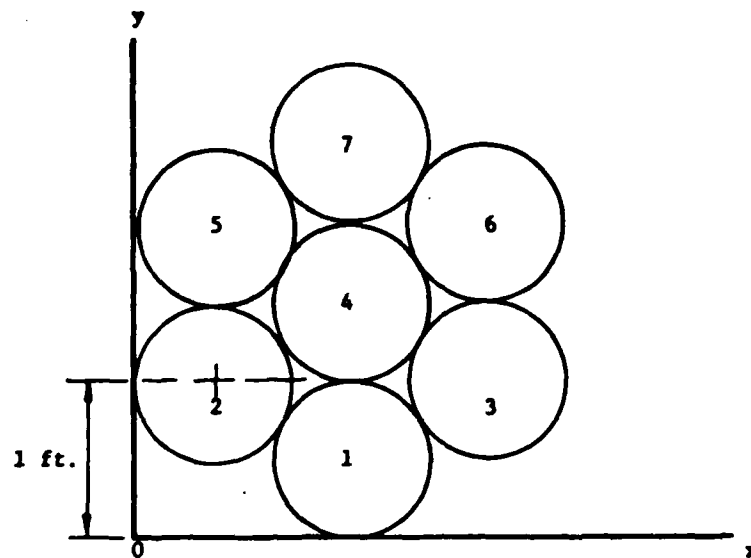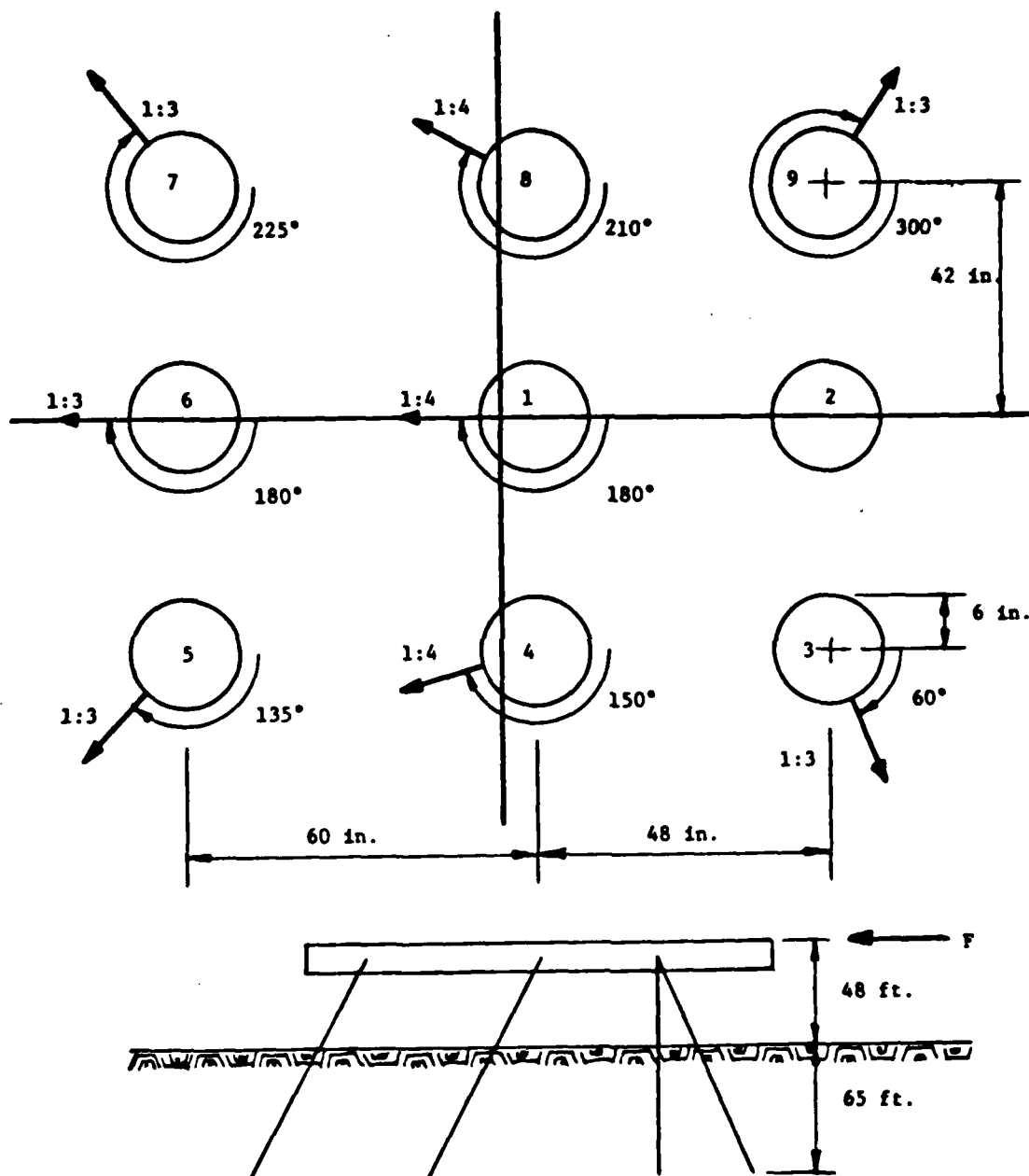
Example 1

In order to demonstrate the use of the distribution factor (D.F.) as applied to pile supported fenders, the following wooden system will be examined, as shown in Figure 11. The parameters relative to this system are;

Length of pile (l) = 34 ft.

Pile Spacing (λx) = 80 in.

Width of system = 720 in.

Modulus of Elasticity E = 1600.ksi (pile & walers)

I pile = .0491d^4 = 19,180.in^4 (25"ϕ)

I waler = $\frac{1}{12}$ bd^3 = 833.in^4 (10"x10")

Fenders not used (K = 0.0)

The ship parameters are;

Weight of Ship = 10,000 ton (20,000. kip)

Velocity of ship (v_i) = 0.40 knot (8.21 in/sec)

The general pile system will be examined under three variations in lateral stiffness.

Case I will have only one waler at the top of the pile (λy = 34 ft.), the second condition Case II, the walers will be spaced at (λy = 5'-7"), and the last Case III, will have walers at λy = 1.0 ft. intervals.

The solutions for each of these cases are as follows;

CASE I

System of vertical piles with no fenders, shown in Fig. 11, with only one waler at the top. The plate is modeled by smearing the stiffness over the total area (D x L), which gives;

$$DY = \frac{(EI_y)_{pile}}{\lambda_x} = \frac{(1600 \; k/in^2) \; (19,180.in^4)}{(720/9)in} = 3.84 \times 10^5 k\text{-}in \; (use \; 4 \times 10^5)$$

$$DX = \frac{(EI_x)_{valer}}{\lambda_y} = \frac{(1600 \text{ k/in}^2)(833 \text{ in}^4)}{34(12) \text{ in}} = 3.3 \times 10^3 \text{ k-in} \quad (\text{use } 3 \times 10^3)$$

from Figure 9, using L = 34 ft., DY = 4.0×10^5 and DX = 3×10^3, then D.F. = .300. With this information the induced stresses, as computed by the two methods are computed as follows;

1) Force Acceleration:

Apply Eq. (1), and assuming Δs = 20 in., gives;

<u>Applied Force</u>

$$F_a = M(v_1^2)/2\Delta s$$

$$F_a = (\frac{20,000.}{32.2}) \; \frac{(8.21)^2}{2(20/12)} \times \frac{1}{144} = 87.2^k$$

<u>Resisting Force</u>

$$F_r = 3\Delta sE(I/D.F.)/L^3 + \Sigma k\Delta s$$

$$F_r = 3(20) \; (1600.) \; (\frac{19,180}{.300})/(34 \times 12)^3$$

$$F_r = 100.2^k$$

$$F_r > F_a \therefore \text{ OK}$$

<u>Moment</u>

$$M = F_a L = 87.2 \times (34 \times 12) = 35,577.6 \text{ k-in.}$$

<u>Stress</u>

$$\sigma = M/(S/D.F.), \text{ where } S = \frac{19,180.}{12.5} = 1534. \text{in}^3, \text{ D.F.} = .300$$

$$\sigma = \frac{35577.6}{1534.} \times .300$$

$$\sigma = 6.9 \text{ ksi} < \sigma_u = 7 \text{ ksi (assumed)}$$

without D.F., σ = 21 ksi

11) Kinetic Energy: Applying Eq. (5) the induced energy is computed as;

$$E_{in.} = \frac{1}{2} M v_n^2 \, (C_H)(C_s)(C_c)(C_E)$$

$$E_{in.} = \frac{1}{2} \left(\frac{20,000.}{32.2}\right) \frac{(8.21)^2}{144} (1.825) \, (1) \, (1) \, (1)$$

where: $C_H = 1 + \frac{2D}{B}$, D = 33 ft., B = 80 ft.

$C_H = 1.825$ $C_s = 1$, $C_c = 1$, $C_E = 1$

therefore: $E_{in.} = 181.5$ k ft = 2178. k-in.

The output energy of the system, given by Eq. (6), is;

$$E_o = F^2 L^2 / (3EI/D.F.)$$

$$E_o = F^2 (12 \times 34)^2 / (3 \times 1600. (19180./.300))$$

$$E_o = F^2 \, (.221)$$

Equation $E_o = E_{in}$ gives

$$2178. = F^2 \times .221$$

$$F^2 = 9855.2$$

$$F = 99.3 \text{ k}$$

Moment:

M = F x L = 99.3x(34x12) 0,514.4 = k in

Stress:

$$\sigma = M/(S/D.F.) = \frac{40,514.4}{(1534/.30)} = 7.9 \text{ ksi} > 7.0 \text{ ksi}$$

Marginal

CASE II

This case is similar to Case I, except the walers are now placed at 5'-7" intervals. This will provide a change in the Dx stiffness, which is:

$$D_x = \frac{(EI_x) \text{waler}}{\lambda y} = \frac{(1600)\,(833.)}{67} = 1.98 \times 10^4 \text{ k-in}$$
$$(\text{Use } 2 \times 10^4)$$

144

$$D_y = \frac{(EI_{y\ pile})}{\lambda y} = \frac{(1600)\ (19,150.)}{720} = 3.84 \times 10^5 \text{ k-in}$$
$$(\text{Use } 4 \times 10^5)$$

Examining Figure 9, gives D.F. = .220

    i)   Force Accelerations

        As given in CAse I, $F_a = 87.2^k$,

        the resisting force is computed as;

$$F_r = 100.2(.300/.220) = 136.6^k$$

$$F_r > F_a \therefore \text{Section OK.}$$

        the induced stress is;

$$\sigma = 6.9(.220/\ 300) = 5.06 \text{ ksi} < 7.0 \text{ ksi} \therefore \text{ OK.}$$

    ii)   Kinetic Energy:

$$E_{in} = 2178.\text{kin.}$$
$$E_o = F^2(.221)\ (.220/.300) = .162F^2$$

        Equating $E_o = E_{in}$ gives the induced force F of;

$$2178. = F^2 \times .162; \ F = 116.^k$$

        the induced stress is therefore;

$$\sigma = 7.9((.22/.30)\ (116./99.3) = 6.8 \text{ ksi} < 7.0 \text{ ksi}$$

CASE III

    This final case consists of walers spaced at 1.0 ft. intervals,

thus
$$D_x = \frac{(EI_x)\text{walers}}{\lambda y} = \frac{(1600)\ (833.)}{12} = 1.1 \times 10^5 \text{k-in.}$$
$$(\text{Use } 1 \times 10^5 \text{k-in})$$

$$D_y = 3.84 \times 10^5 \text{k-in (Use } 4 \times 10^5 \text{k-in)}$$

Using Figure 9, D.F. = .15

i) Force Acceleration

As given in Case I, $F_a = 87.2^k$

the resisting force is computed as;

$$F_r = 100.2(.300/.15) = 200.4^k$$

$$F_r > F_a \; \therefore \; \text{Section OK}$$

The induced stress is:

$$\sigma = 6.9(.150/.300) = 3.45 \text{ ksi} < 7.0 \text{ ksi}$$

ii) Kinetic Energy

$$E_{in} = 2.78.0 \text{ k-in.}$$

$$E_o = F^2(.221)\ (.150/.300) = .110\ F^2$$

equating $E_o = E_{in}$ gives the induced force F;

$$2178 = F^2 \times .110$$

$$F = 140.7^k$$

The induced stress is therefore;

$$\sigma = 7.9(.15/.30)\ (140.7/99.3) = 5.6 \text{ ksi} < 7.0 \text{ ksi}$$

A comparison of the results are shown in Table 2, and show the effect the walers have on the reduction of stress on the piles, through lateral distribution of load. Also shown in the table are the results obtained from a computer simulations model (1).

146

TABLE 1

CASE	λx(in)	λy(in)	$D_y \times 10^5$(k-in)	$D_x \times 10^3$(k-in)
1.	90.	408.	4.0	3.0
2.	90.	67.	4.0	20.
3.	90.	12.	4.0	100.

TABLE 2

| | METHOD | | | | COMPUTER | |
| | Force Acceleration | | Kinetic Energy | | | |
CASE NO.	Force(k)	Stress(ksi)	Force(k)	Stress(ksi)	Force(k)	Stress(ksi)
1.	87.2	6.9	99.3	7.9	139.7	----
2.	87.2	5.06	116.	6.8	107.	---
3.	87.2	3.45	140.7	5.6	85.0	---

$L = 34'$

$720''$

$\lambda_x = 80''$
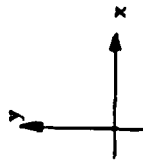
FIGURE 11

Case I $\lambda_y = 34'$

Case II $\lambda_y = 5'-7''$
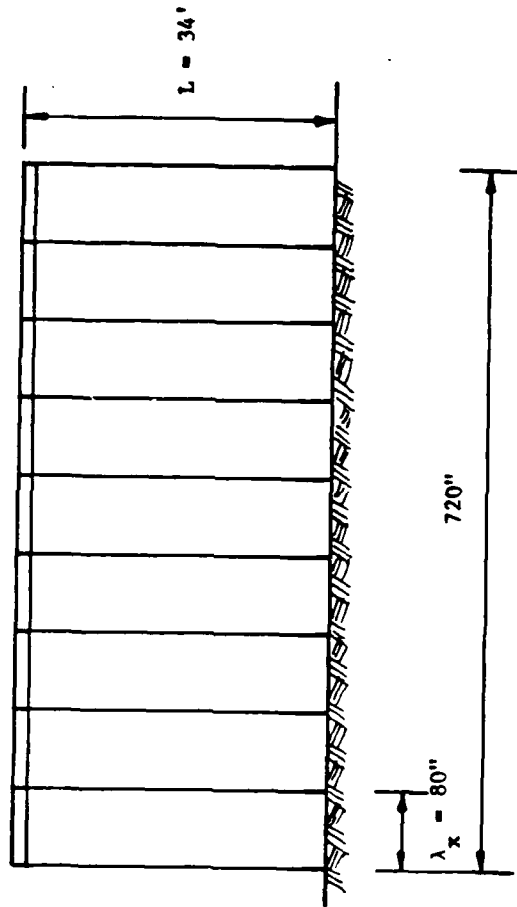
Case III $\lambda_y = 1'$

EXAMPLE 2

The docking of vessels in a port facility requires a structural
system which can support the impact of the vessel, continue to be
serviceable, have easy maintenance at a minimum cost.

In general, the warf or dock contains a front battered pile
with possible walers and absorbing devices, as shown in Figure 12.
In many instances, bulbus bow ships will shear off the bottom of
the front pile, without any noticeable damage to the top of the
pile until an inspection is made.

Thus, it is apparent that a new structural system or systems
should be devised to remedy this problem and contain the following
features:

1. Minimum Construction

2. Minimum Cost

3. Easily Maintained

4. Structurally Sound

5. Reasonable Life

This criteria can be met with improved technology and engineering
judgment, an example of which will be described herein.

Problem

One of the major problems of a port, as mentioned previously, is the shearing off of pilings due to various types of ships. The design of a proper system to eliminate such a condition, and to provide a reasonable life to the system, will be given by considering a front vertical piling with a suspended wooden bulkhead with attached absorbing device. This example is only given to illustrate what may be done and how it may be technically accomplished.

The general plan of the system is shown in Figure 13, and consists of a series of vertical piles with a suspended wooden bulkhead and attached fenders. The bulkhead is supported laterally by a series of channels, Fig. 14, which slide along the W shape flange. Repair and removal of the bulkhead can easily be performed by maintenance personnel.

Solution

a) Analytical Solution

The response of the pile system will be determined by utilization of a series of recently developed distribution factor (D.F.) curves which are based on plate and girder theories and consider lateral interaction of the walers or grid. This interaction is incorporated in the design by evaluation of the longitudinal (D_y) and transverse (D_x) stiffness of the system, as shown in Figure 15.

As shown in Figure 14, the bulkhead is assumed to consist of fifteen 6" x 12" treated wooden horizontal members spaced at 2'. The vertical members comprise six 12" x 12" treated wooden members spaced at 2'. The stiffness of this unit is computed as follows:

$\underline{D_y}:$

$$D_y = EI/\lambda x = \frac{1600. \times 1728}{10 \times 12} = 23040. \text{ K-in}^2/\text{in.}$$
$$\text{Use } (2 \times 10^4 \text{ K-in})$$

$\lambda x = 10'$

$E = 1600. \text{ ksi}$

$I = \frac{1}{12} (12)(12)^3 = 1728 \text{ in}^4$

$\underline{D_x}:$

$$D_x = EI/\lambda y = \frac{1600. \times 1728}{60 \times 12} = 3840. \frac{\text{K-in}^2}{\text{in.}}$$
$$\text{Use } (4 \times 10^3 \text{ K-in})$$

$\lambda y = 60'$

$E = 1600. \text{ ksi}$

$I = \frac{1}{12} (12)(12)^3 = 1728 \text{ in}^3$

151

using now the general energy equation

$$F = M_v{}^2/2\Delta \text{ gives:}$$

$$F_a = M_{v_i}{}^2/2\Delta_s$$

Assume $\Delta_s = 20"$, and for a ship W = 10,000 tons and $v_i = 0.40$ knots, then the applied force is;

$$F_a = (\frac{20000.}{32.2}) \frac{(8.21)^2}{2 \times 20/12} + \frac{1}{44} = 87.2^K$$

The resulting force of the steel pile is:

$$F_r = 3\Delta_s E (I/D.F.)/L^3 + K\Delta_s$$

assuming no fenders then K = 0 and $F_r = F_a$, gives;

$$87.2 = 3\Delta_s E (I/D.F.)/L^3, \text{ solving for I and letting}$$

D.F. = 1.0, gives;

$$F_r = 87.2 = 3\Delta_s E(I/D.F.)/L^3 + \Sigma K\Delta_s$$

$$I_{eq} = \frac{87.2 \times (60 \times 12)^3}{3 \times 20 \times 30 \times 10^3}$$

or: $I_{req} = 18081.8$ in^4

Try W36 x 280   (I = 18,900. in^4)

$$M = 87 \times 60 \times 12 = 62640. \text{ k-in.}$$

$$f = \frac{62640}{1030} = 60 \text{ ksi   (H.S. - steel)}$$

However if lateral top support is provided;

$$M_{max} = \frac{3}{16} PL$$

$$f = 60 \times 3/16 = 11.4 \text{ ksi ok.}$$

Bulkhead Effect

for $D_y = 2 \times 10^4$ k-in and D_x k-in and $D_x = 4 \times 10^3$ k-in

then the distribution factor; DF = .13; (Fig. 16)

therefore:

$I_{req} = 18081.8 \times .13$

$I_{req} = 2350.$ in^4

use W24 x 84   (I = 2370 in^4) and   S = 197 in^3

M = 720 x 87 = 62640

$f = \dfrac{62640 \times .13}{197} = 41$ ksi

top support

f = 41 x 3/16 = 7.25 ksi; therefore o.k.

reduction in weight 280 to 84# per foot, or a

saving of 200#/ft along the pile length.

Critical Pile

FIGURE 12

Wood Bulk Hd

Fender

Elev. End

60'

30'

10' 10' 10' 10' 10'

Plan

FIGURE 13

w/HP Pile
Roof Dirrbr
Steel [
Bulk Hd.
Fender

Center Support

Separate Blkhd.

sym.
12" x 12'
6" x 12"
2'
2'
Bulk Hd.

FIGURE 14

156

FIGURE 15

157

DY = Constant = $2(10^4)$

DX = $4(10^3)$
DX = $8(10^3)$
DX = $2(10^4)$
DX = $6(10^4)$
DX = $1(10^4)$

L(ft.)

DF
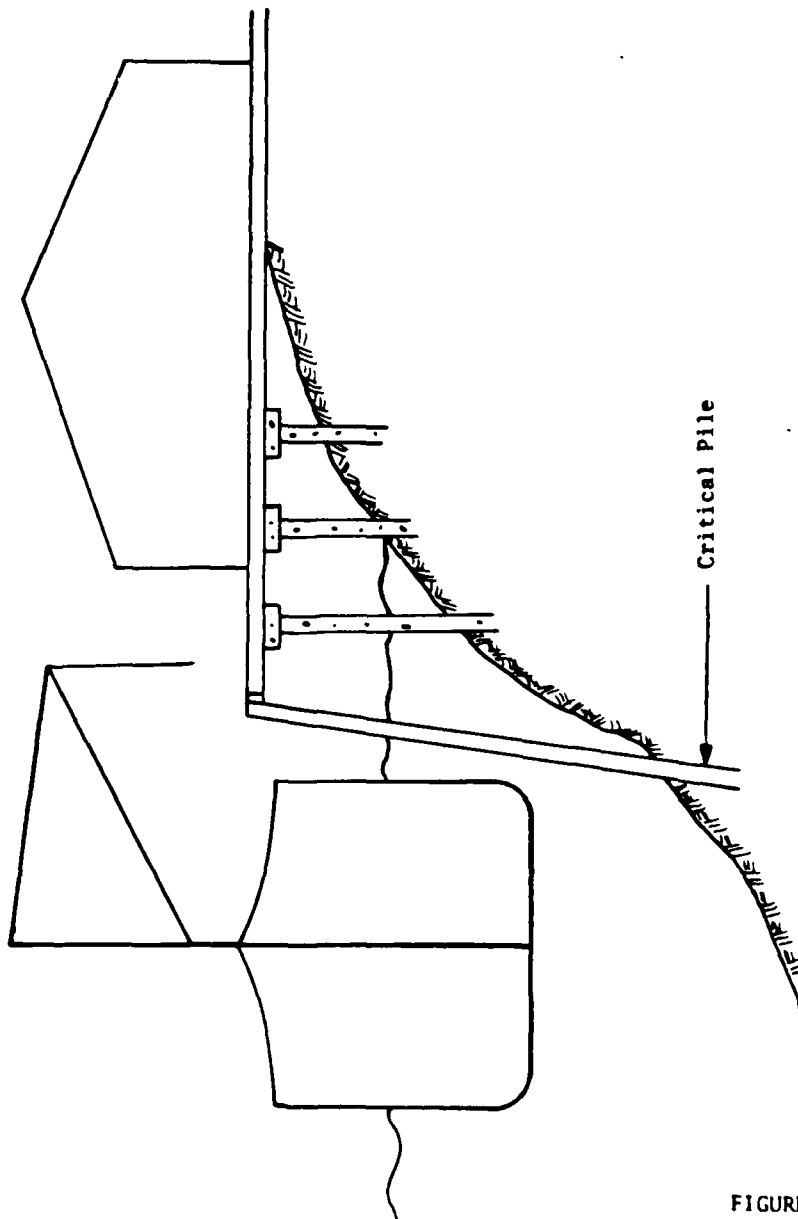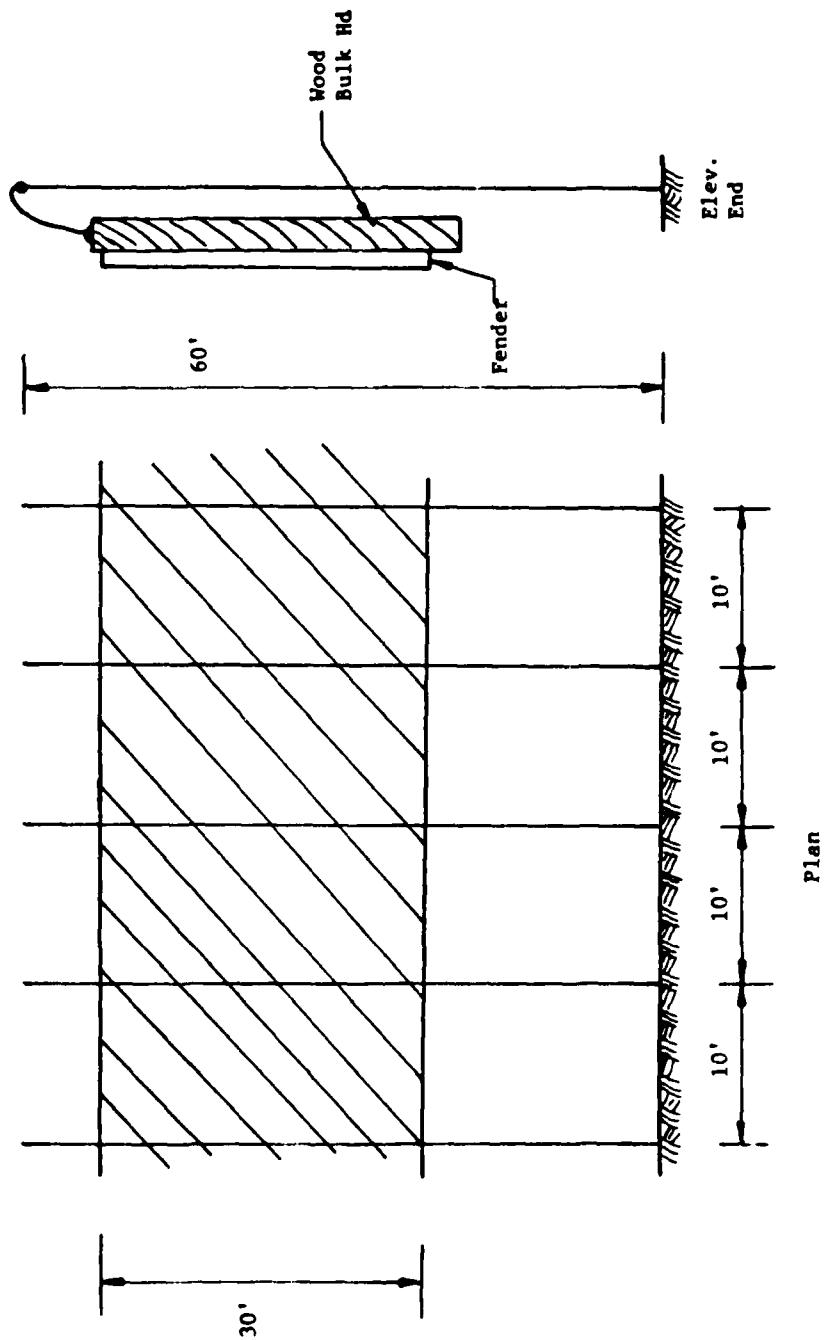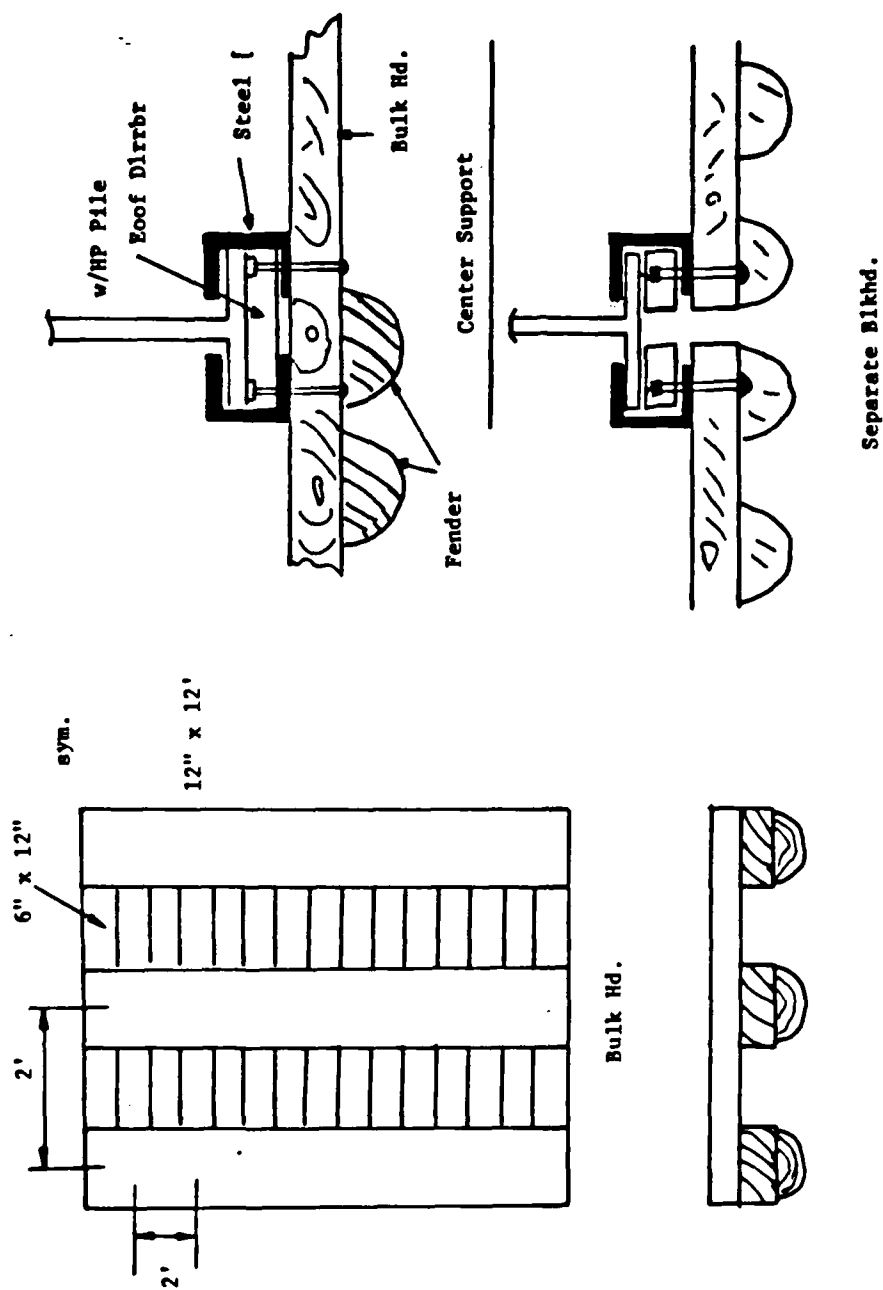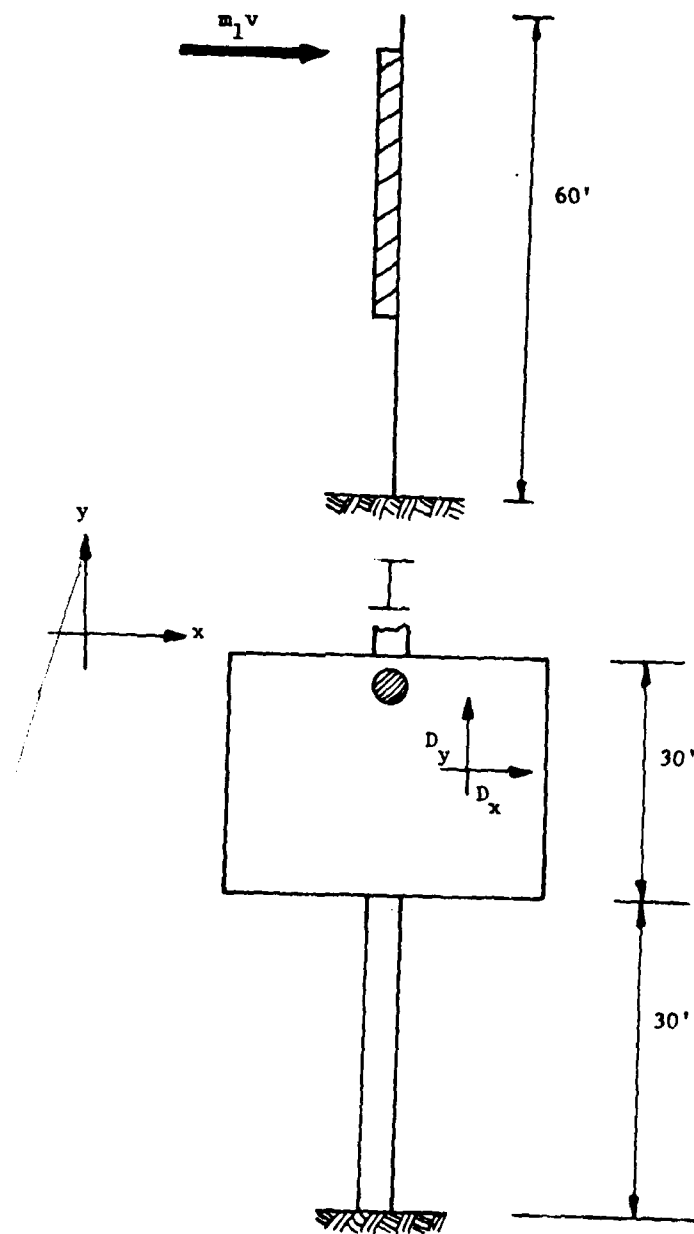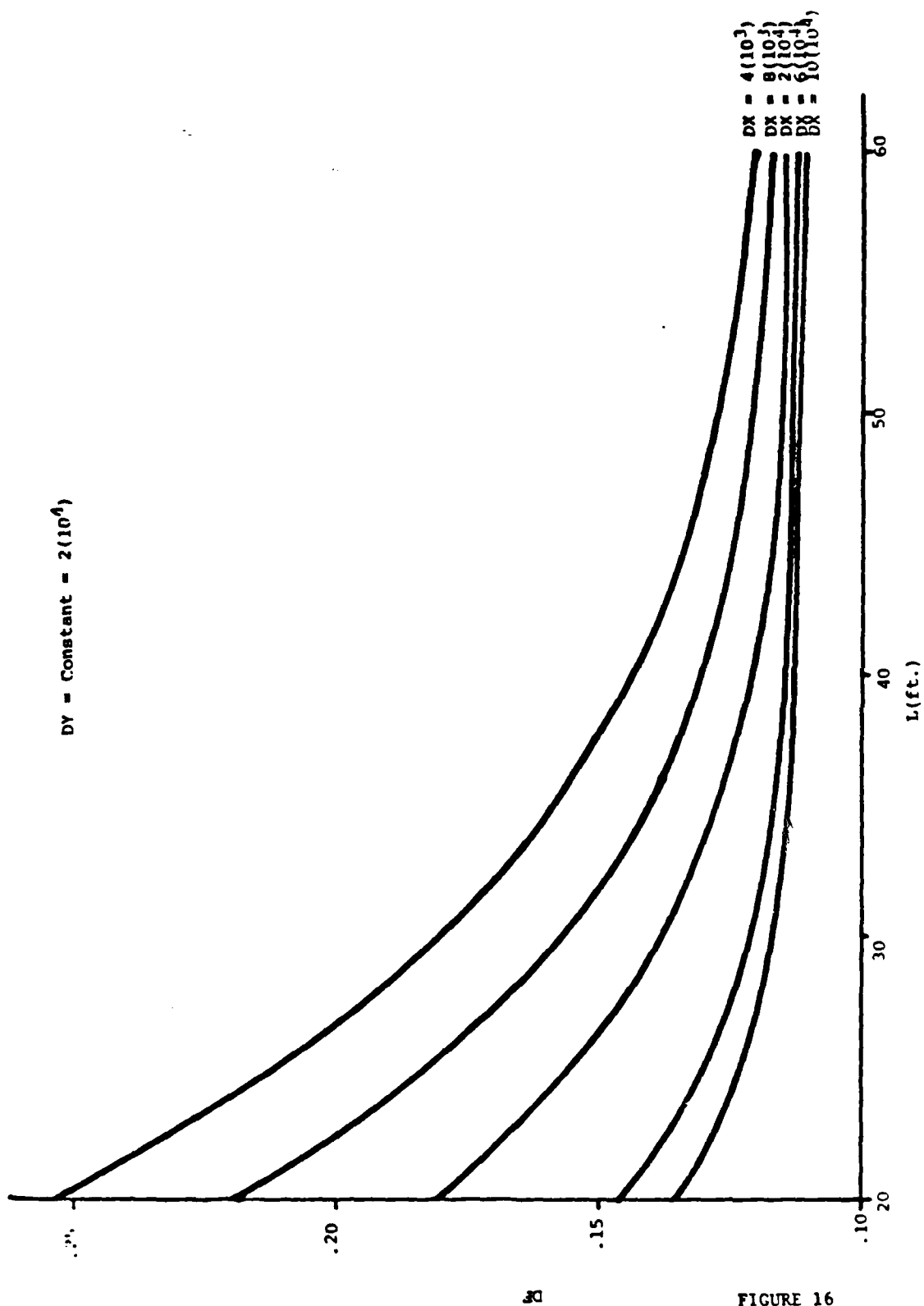
FIGURE 16

EXAMPLE 3

MOORING DOLPHIN

1) Classical Solution

As described previously the classical energy methods can be applied to the design of a mooring dolphin, arranged as shown in Figure 17, with a free cantilever length of 48' and HP 14 x 73 steel sections. The dolphin is impacted with a 25,000 ton vessel at a velocity of 0.50 ft/sec.

The induced dynamic force is given by;

$$F = M_a = M(v_1^2 - v_f^2)/2\Delta$$

where: $M = 1,750,000$ for 25,000 ship

$v_1 = 0.5$ ft/sec.

$\Delta = 6$ in. (assumed)

The force $F = \dfrac{1.75 \times 10^6 \times (0.5)^2}{2 \times 0.5} = 437.5^K$

Considering a cantilever pile:

$\Delta = PL^3/3EI$

or the required stiffness is;

$I_r = PL^3/3E\Delta$ or

$I_r = \dfrac{437.5 \times (48)^3 \times 1728}{3 \times 29 \times 10^3 \times 0.5}$

$I_r = 160,167.7$ in.^{4}

Assuming a nine pile grouping, as shown in Figure 17, then I_{act} is computed as;

$I_{act} = 6[I_o + \Delta(36)^2] + 3 \times I_o$

159

assuming a HP 14 x 73 section (I_o = 734.in^4, A = 21.5 in^2), gives;

$$I_{act} = 6 [734. + 2.15 (36)^2] + 3 \times 734$$

$$I_{act} = 173,790 \ in^4 > 160,167.7 \ in.^4$$

Therefore stiffness is satisfied. Assuming the load to each pile is P = 437.5/9 = 48.6, then the moment is M = 48.6 x 48 = 2333.3 k-ft. the induced stress is therefore;

$$f = \frac{2333.3 \times 12}{108} = 259 \ ksi$$

if the group action is assumed then

$$f = \frac{437.5 \times (48 \times 12)}{173790} \times 36 = 52 \ ksi$$

which indicates an over stressed condition.

ii) Computer Solution

The same mooring dolphin has been examined by a dynamic system.

The results of the computer analysis indicate that under impact of the ship, the maxim deformation will be 4.0 in. when subjected to an imapct force of 1721. kips. The bending stress at the mud line for each pile is;

Pile No.	Stress(ksi)	Deflection(in)
1	10.1	4.0
2	0.	0.
3	9.1	3.5
4	5.1	3.6
5	9.1	3.5
6	0.	0.
7	9.1	3.5
8	5.1	3.6
9	9.1	3.5

160

A summary of the output dynamic data and energy is given in Tables 3 and 4.

A summary of the results shows the system is adequate relative to the strength of the steel sections and soil.

PIER DOLPHIN

i) Classical Solution

The second problem under study consists of five pairs of steel HP 14 x 73 sections (one vertical/one battered) connected by a rigid pier cap, as shown in Fig. 18. The pier will be impacted by a 25,000 Ton vessel at 6 ft/sec.

$$F = M_a = \frac{W}{g} (v^2)/2\Delta$$

the weight of ship is $50,000^K$, and $\Delta = 3$ in, $v_1 = 0.5$ ft/sec, which gives;

$$F = \frac{50,000.}{32.2} \left(\frac{(.5)^2}{2x.25}\right)$$

$$F = 776^K$$

assume a five pile group, therefore;

$$P = 776/5 = 155^K$$

Assuming a batter of 1/2, then the force on the piling is:
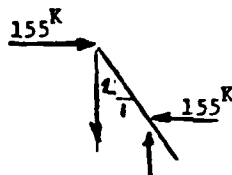
$$V = 2 \times 155 = 310^K$$

Considering a HP x 73 section (A = 21.46 in^2), the induced stress is

$$f = 310/21.46 = 14.4 \text{ ksi}$$

ii) Computer solution

Application of the computer program results in a maximum force of 2148.K, inducing a maximum deformation of 1.4 in. and a stopping time of .44 seconds to the system. The resulting stresses

for each pile are as follows;

Pile No.	Stress(ksi)	Deflection(in)
1	3.2	1.3
2	3.2	1.3
3	0.2	.67
4	7.0	1.5
5	7.0	1.5
6	7.0	1.5
7	7.0	1.5
8	7.0	1.5
9	2.0	1.2
10	3.2	1.3

The results indicate adequate strength of the steel elements and soil. However the size of the pile could be drastically reduced. A tabulation of the data is given in Tables 5 and 6.

12'-6"

HP 14 x 73 (Typ)

3' Typ

5'

164
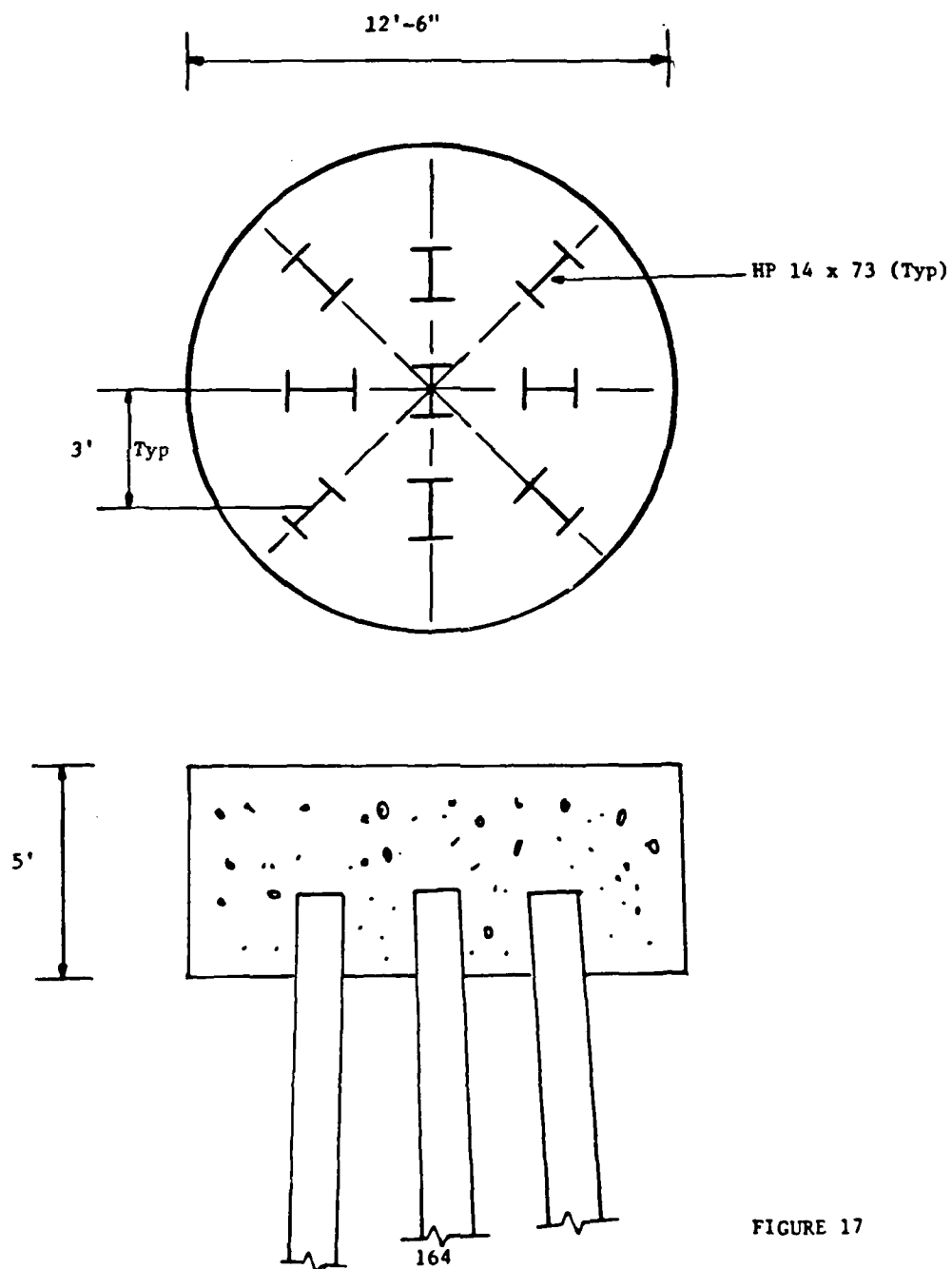
FIGURE 17

FIGURE 18

165
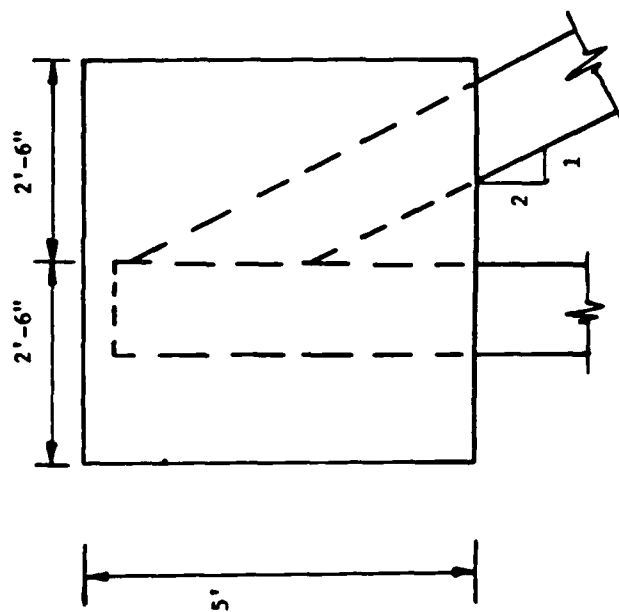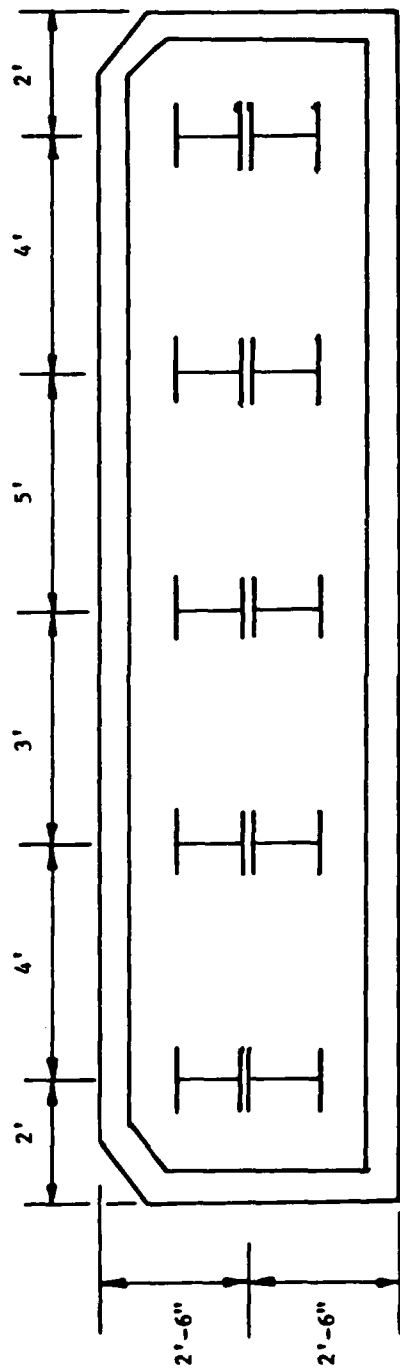
BASIC PROGRAM PARAMETERS

```
              WEIGHT OF SHIP =    25000.00 TONS  (  56000.00 KIPS)
              VELOCITY OF SHIP =       .32 KNOTS  (      6.49 IPS)
    LENGTH OF DOLPHIN BELOW ML =     65.00 FEET
    LENGTH OF DOLPHIN ABOVE ML =     45.00 FEET
                  MASS OF SHIP =    145.05 KIPS/IN/SEC/SEC
      ANGLE OF PASSIVE FAILURE =     45.00 DEGREES
              DEPTH CORRECTION =        .00 FEET
            DISSIPATION FACTOR =      .5000
              ALLOWABLE STRAIN =    .03000 IN/IN
```

TABLE 3   PAGE   74

PILE # 1 /SOIL LOADS AND DEFORMATIONS AT TIME =   .9358E6SECONDS

DEPTH BELOW M.L. (IN)	SOIL MODULUS (K/SQ IN)	SOIL RESISTANCE ALLOW. (K/IN)	SOIL RESISTANCE ACTUAL (K/IN)	PILE 1 DEFL. DEFL. (IN)	PILE 1 DEFL. SLOPE (RAD)	PILE 1 M AND V MOMENT (IN-K)	PILE 1 M AND V SHEAR (K)
TOP 0.0	.00	.0	.0	4.005	.010	0.	1702.9
0.0	.000	.0	.0	.095	.001	1076.	1692.0
39.0	23.40	273.4	1.6	.068	.001	3725.	1644.4
78.0	46.50	546.0	2.0	.043	.001	9575.	1571.2
117.0	70.20	820.3	1.6	.023	.000	12319.	1509.6
156.0	93.60	1093.7	.9	.010	.000	11064.	1474.5
195.0	117.00	1367.1	.2	.002	.000	8451.	1465.6
234.0	140.40	1640.6	-.0	-.002	.000	5452.	1475.7
273.0	163.80	1914.0	-.3	-.003	-.000	2866.	1494.8
312.0	187.20	2187.4	-.4	-.003	-.000	1027.	1516.8
351.0	210.60	2460.7	-.2	-.002	-.000	-34.	1530.5
390.0	234.00	2734.1	-.1	-.001	-.000	-481.	1540.0
429.0	257.40	3007.7	-.1	-.000	-.000	-540.	1545.1
468.0	280.80	3281.1	-.0	-.000	-.000	-413.	1546.3
507.0	304.20	3554.6	.0	.000	-.000	-241.	1545.5
546.0	327.60	3828.0	.0	.000	.000	-111.	1544.2
585.0	351.00	4101.4	.0	.000	.000	-25.	1543.0
624.0	374.40	4374.9	.0	.000	.000	11.	1542.2
663.0	397.80	4648.3	.0	.000	.000	22.	1541.8
702.0	421.20	4921.7	.0	.000	.000	15.	1541.7
741.0	444.60	5195.2	-.0	-.000	.000	5.	1541.8
780.0	468.00	5468.6	-.0	-.000	.000	0.	1542.0

DOLPHIN/SOIL LOADS AND DEFORMATIONS AT TIME =   .9358E6 SECONDS

DEPTH BELOW M.L. (IN)	BENDING ALLOWABLE (KSI)	BENDING ACTUAL (KSI)	SHEAR ALLOWABLE (KSI)	SHEAR ACTUAL (KSI)	COMBINED STRESS RATIO
0.0	23.80	10.11	14.40	197.91	189.325
39.0	23.80	50.04	14.40	191.60	179.142
78.0	23.80	69.98	14.40	183.07	165.409
117.0	23.80	115.76	14.40	175.92	154.109
156.0	23.80	103.97	14.40	171.50	148.706
195.0	23.80	79.23	14.40	170.77	145.956
234.0	23.80	51.21	14.40	171.94	144.723
273.0	23.80	26.92	14.40	174.17	147.423
312.0	23.80	9.65	14.40	176.30	150.630
351.0	23.80	-.32	14.40	178.33	153.562
390.0	23.80	-4.32	14.40	179.49	155.556
429.0	23.80	-5.07	14.40	180.04	156.527
468.0	23.80	-3.90	14.40	180.17	156.702
507.0	23.80	-2.27	14.40	180.08	156.682
546.0	23.80	-1.04	14.40	179.92	156.156
585.0	23.80	-.24	14.40	179.78	155.881
624.0	23.80	.13	14.40	179.69	155.718
663.0	23.80	.21	14.40	179.65	155.644
702.0	23.80	.14	14.40	179.64	155.625
741.0	23.80	.05	14.40	179.65	155.647
780.0	23.80	.00	14.40	179.67	155.671

PILE # 2 /SOIL LOADS AND DEFORMATIONS AT TIME = .93586SECONDS

DEPTH BELOW M.L. (IN)	SOIL MODULUS (K/SQ IN)	SOIL RESISTANCE ALLOW. (K/IN)	ACTUAL (K/IN)	PILE 2 DEFL. DEFL. (IN)	SLOPE (RAD)	PILE 2 P AND V MOMENT (IN-K)	SHEAR (K)
TOP	.00	.0	.0	.000	.000	0.	1706.9
.0	.00	.0	.0	.000	.000	0.	1706.9
39.0	23.40	273.4	.0	.000	.000	0.	1706.9
78.0	46.80	546.9	.0	.000	.000	0.	1706.9
117.0	70.20	820.3	.0	.000	.000	0.	1706.9
156.0	93.60	1093.7	.0	.000	.000	0.	1706.9
195.0	117.00	1367.1	.0	.000	.000	0.	1706.9
234.0	140.40	1640.6	.0	-.000	.000	0.	1706.9
273.0	163.80	1914.0	-.0	-.000	.000	0.	1706.9
312.0	187.20	2187.4	-.0	-.000	-.000	-0.	1706.9
351.0	210.60	2460.9	-.0	-.000	-.000	-0.	1706.9
390.0	234.00	2734.3	-.0	-.000	-.000	-0.	1706.9
429.0	257.40	3007.7	-.0	-.000	-.000	-0.	1706.9
468.0	280.80	3281.1	-.0	-.000	-.000	-0.	1706.9
507.0	304.20	3554.6	.0	.000	-.000	-0.	1706.9
546.0	327.00	3828.0	.0	.000	.000	-0.	1706.9
585.0	351.00	4101.4	.0	.000	.000	-0.	1706.9
624.0	374.40	4374.9	.0	.000	.000	0.	1706.9
663.0	397.80	4648.3	.0	.000	.000	0.	1706.9
702.0	421.20	4921.7	.0	.000	.000	0.	1706.9
741.0	444.60	5195.2	-.0	-.000	.000	0.	1706.9
780.0	468.00	5468.6	-.0	-.000	.000	0.	1706.9

DOLPHIN/SOIL LOADS AND DEFORMATIONS AT TIME = .935E6 SECONDS

DEPTH BELOW M.L. (IN)	BENDING ALLOWABLE (KSI)	ACTUAL (KSI)	SHEAR ALLOWABLE (KSI)	ACTUAL (KSI)	COMBINED STRESS RATIO
.0	23.80	.00	14.40	199.11	191.193
39.0	23.80	.00	14.40	199.11	191.193
78.0	23.80	.00	14.40	199.11	191.193
117.0	23.80	.00	14.40	199.11	191.193
156.0	23.80	.00	14.40	199.11	191.193
195.0	23.80	.00	14.40	199.11	191.193
234.0	23.80	.00	14.40	199.11	191.193
273.0	23.80	.00	14.40	199.11	191.193
312.0	23.80	.00	14.40	199.11	191.193
351.0	23.80	-.00	14.40	199.11	191.193
390.0	23.80	-.00	14.40	199.11	191.193
429.0	23.80	-.00	14.40	199.11	191.193
468.0	23.80	-.00	14.40	199.11	191.193
507.0	23.80	-.00	14.40	199.11	191.193
546.0	23.80	-.00	14.40	199.11	191.193
585.0	23.80	.00	14.40	199.11	191.193
624.0	23.80	.00	14.40	199.11	191.193
663.0	23.80	.00	14.40	199.11	191.193
702.0	23.80	.00	14.40	199.11	191.193
741.0	23.80	.00	14.40	199.11	191.193
780.0	23.80	.00	14.40	199.11	191.193

PILE # 3 /SOIL LOADS AND DEFORMATIONS AT TIME = .93586 SECONDS

DEPTH BELOW M.L. (IN)	SOIL MODULUS (K/SQ IN)	SOIL RESISTANCE ALLOW. (K/IN)	SOIL RESISTANCE ACTUAL (K/IN)	PILE 3 DEFL. (IN)	PILE 3 DEFL. SLOPE (RAD)	PILE 3 P MOMENT (IN-K)	PILE 3 V SHEAR (K)
TOP 0	.00	.0	.0	-3.509	-.009	0.	1706.9
39.0	23.40	273.4	-1.6	-.063	-.001	-971.	1717.9
78.0	46.80	546.9	-1.8	-.050	-.001	-4691.	1765.4
117.0	70.20	820.3	-1.4	-.038	-.000	-8411.	1629.6
156.0	93.60	1093.7	-.6	-.028	-.000	-10811.	1683.4
195.0	117.00	1367.1	.1	-.001	-.000	-9706.	1914.3
234.0	140.40	1640.6	.3	-.002	-.000	-7394.	1922.1
273.0	163.80	1914.0	.5	-.003	-.000	-4780.	1915.2
312.0	187.20	2187.4	.4	-.002	-.000	-2511.	1690.4
351.0	210.60	2460.9	.2	-.001	-.000	-899.	1678.9
390.0	234.00	2734.3	.1	-.000	-.000	31.	1665.1
429.0	257.40	3007.7	.1	-.000	-.000	422.	1656.4
468.0	280.80	3281.1	.0	-.000	-.000	474.	1652.0
507.0	304.20	3554.6	-.0	-.000	-.000	364.	1651.3
546.0	327.60	3828.0	-.0	-.000	-.000	218.	1655.0
585.0	351.00	4101.4	-.0	-.000	-.000	97.	1653.1
624.0	374.40	4374.9	-.0	-.000	-.000	22.	1654.2
663.0	397.80	4648.3	-.0	-.000	-.000	-12.	1654.9
702.0	421.20	4921.7	-.0	-.000	-.000	-19.	1655.2
741.0	444.60	5195.2	-.0	-.000	-.000	-13.	1655.3
780.0	468.00	5468.6	.0	.000	-.000	-4.	1655.2
						0.	1655.0

DOLPHIN/SOIL LOADS AND DEFORMATIONS AT TIME = .93586 SECONDS

DEPTH BELOW M.L. (IN)	BENDING ALLOWABLE (KSI)	BENDING ACTUAL (KSI)	SHEAR ALLOWABLE (KSI)	SHEAR ACTUAL (KSI)	COMBINED STRESS RATIO
39.0	23.80	-9.11	14.40	200.16	193.598
78.0	23.80	-44.08	14.40	205.70	205.904
117.0	23.80	-79.04	14.40	213.18	222.479
156.0	23.80	-101.59	14.40	219.44	336.502
195.0	23.80	-91.21	14.40	223.05	341.766
234.0	23.80	-69.48	14.40	223.96	341.798
273.0	23.80	-44.92	14.40	222.92	341.539
312.0	23.80	-23.60	14.40	220.96	336.449
351.0	23.80	-8.29	14.40	218.95	231.466
390.0	23.80	3.97	14.40	217.31	225.786
429.0	23.80	3.45	14.40	216.30	225.769
468.0	23.80	2.04	14.40	215.82	224.810
507.0	23.80	.91	14.40	215.71	224.533
546.0	23.80	.21	14.40	215.78	224.675
585.0	23.80	-.13	14.40	215.92	225.100
624.0	23.80	-.18	14.40	216.04	225.262
663.0	23.80	-.12	14.40	216.12	225.286
702.0	23.80	-.04	14.40	216.17	225.353
741.0	23.80	.00	14.40	216.16	225.331
780.0	23.80		14.40	216.14	225.302

PILE # 4 /SOIL LOADS AND DEFORMATIONS AT TIME = .93586 SECONDS

DEPTH BELOW M.L. (IN)	SOIL MODULUS (K/SQ IN)	SOIL RESISTANCE ALLOW. (K/IN)	ACTUAL (K/IN)	PILE 4 DEFL. (IN)	SLOPE (RAD)	PILE 4 M AND V MOMENT (IN-K)	SHEAR (K)
TOP .0	.00	.0	.0	-3.614	-.009	0.	1700.9
	.000	.0	.0	-.084	-.001	-541.	1716.0
39.0	23.400	273.4	-1.4	-.060	-.001	-4421.	1790.3
78.0	46.600	546.9	-1.8	-.038	-.001	-8301.	1831.7
117.0	70.200	820.3	-1.5	-.021	-.000	-10838.	1886.8
156.0	93.600	1093.7	-.8	-.009	-.000	-9792.	1916.9
195.0	117.000	1367.1	-.2	-.002	-.000	-7496.	1927.3
234.0	140.400	1640.6	.3	.002	-.000	-4570.	1916.8
273.0	163.800	1914.0	.5	.003	-.000	-2577.	1902.0
312.0	187.200	2187.4	.5	.003	.000	-932.	1894.4
351.0	210.600	2460.9	.4	.002	.000	14.	1870.1
390.0	234.000	2734.3	.2	.001	.000	418.	1861.5
429.0	257.400	3007.7	.1	.000	.000	476.	1857.3
468.0	280.800	3281.1	.0	-.000	.000	369.	1856.2
507.0	304.200	3554.6	-.0	-.000	-.000	222.	1856.9
546.0	327.600	3828.0	-.0	-.000	-.000	100.	1858.0
585.0	351.000	4101.4	-.0	-.000	-.000	23.	1859.1
624.0	374.400	4374.9	-.0	-.000	-.000	-11.	1859.8
663.0	397.800	4648.3	-.0	-.000	-.000	-19.	1860.1
702.0	421.200	4921.7	-.0	-.000	-.000	-13.	1860.2
741.0	444.600	5195.2	-.0	.000	-.000	-4.	1860.1
780.0	468.000	5468.6	.0	.000	-.000	0.	1860.0

DOLFHIN/SOIL LOADS AND DEFORMATIONS AT TIME = .93586 SECONDS

DEPTH BELOW M.L. (IN)	BENDING ALLOWABLE (KSI)	ACTUAL (KSI)	SHEAR ALLOWABLE (KSI)	ACTUAL (KSI)	COMBINED STRESS RATIO
.0	23.80	-5.08	14.40	200.18	193.458
39.0	23.80	-41.54	14.40	205.50	206.000
78.0	23.80	-78.00	14.40	213.42	222.941
117.0	23.80	-101.84	14.40	219.85	237.362
156.0	23.80	-92.02	14.40	223.58	244.940
195.0	23.80	-70.44	14.40	224.57	248.166
234.0	23.80	-45.76	14.40	223.57	242.971
273.0	23.80	-24.21	14.40	221.62	237.875
312.0	23.80	-8.81	14.40	219.56	232.857
351.0	23.80	.13	14.40	217.93	227.045
390.0	23.80	3.93	14.40	216.90	227.027
429.0	23.80	4.47	14.40	216.40	226.027
468.0	23.80	3.47	14.40	216.68	225.734
507.0	23.80	2.08	14.40	216.36	225.072
546.0	23.80	.94	14.40	216.49	226.072
585.0	23.80	.22	14.40	216.62	226.299
624.0	23.80	-.11	14.40	216.70	226.465
663.0	23.80	-.16	14.40	216.74	226.551
702.0	23.80	-.12	14.40	216.75	226.567
741.0	23.80	-.04	14.40	216.74	226.536
780.0	23.80	.00	14.40	216.72	226.507

PILE # 5 /SOIL LOADS AND DEFORMATIONS AT TIME = .935E6 SECONDS

DEPTH BELOW M.L. (IN)	SOIL MODULUS (K/SQ IN)	SOIL RESISTANCE ALLOW. (K/IN)	SOIL RESISTANCE ACTUAL (K/IN)	PILE 5 DEFL. DEFL. (IN)	PILE 5 DEFL. SLOPE (RAD)	PILE 5 M AND V MOMENT (IN-K)	PILE 5 M AND V SHEAR (K)
TOP	.00	.0	.0	-3.509	-.009	0.	1706.9
.0	.000	.0	.0	-.053	-.001	-971.	1717.9
39.0	23.40	273.4	-1.4	-.059	-.001	-4691.	1765.4
78.0	46.80	546.9	-1.2	-.038	-.000	-8411.	1829.6
117.0	70.20	820.3	-1.4	-.020	-.000	-10811.	1883.4
156.0	93.60	1093.7	-.8	-.008	-.000	-9706.	1914.3
195.0	117.00	1367.1	-.4	-.001	-.000	-7394.	1922.1
234.0	140.40	1640.6	.3	.002	-.000	-4780.	1913.2
273.0	163.80	1914.0	.5	.003	-.000	-2511.	1896.4
312.0	187.20	2187.4	.5	.002	.000	-299.	1678.9
351.0	210.60	2460.9	.4	.002	.000	31.	1645.1
390.0	234.00	2734.3	.2	.001	.000	422.	1656.4
429.0	257.40	3007.7	.1	.000	.000	474.	1854.2
468.0	280.80	3281.1	.0	.000	.000	164.	1851.6
507.0	304.20	3554.5	-.0	-.000	.000	215.	1851.6
546.0	327.60	3828.0	-.0	-.000	.000	57.	1853.1
585.0	351.00	4101.4	-.0	-.000	-.000	22.	1854.2
624.0	374.40	4374.9	-.0	-.000	-.000	-12.	1854.9
663.0	397.80	4648.3	-.0	-.000	-.000	-19.	1855.2
702.0	421.20	4921.7	-.0	-.000	-.000	-13.	1855.3
741.0	444.60	5195.2	.0	.000	-.000	-4.	1855.2
780.0	468.00	5468.6	.0	.000	-.000	0.	1855.0

DOLPHIN/SOIL LOADS AND DEFORMATIONS AT TIME = .935E6 SECONDS

DEPTH BELOW M.L. (IN)	BENDING ALLOWABLE (KSI)	BENDING ACTUAL (KSI)	SHEAR ALLOWABLE (KSI)	SHEAR ACTUAL (KSI)	COMBINED STRESS RATIO
.0	23.80	-9.13	14.40	200.16	197.598
39.0	23.80	-44.06	14.40	205.70	205.904
78.0	23.80	-79.04	14.40	213.18	222.479
117.0	23.80	-101.59	14.40	219.44	236.502
156.0	23.80	-91.21	14.40	223.05	243.766
195.0	23.80	-69.48	14.40	223.96	244.798
234.0	23.80	-44.92	14.40	222.92	241.539
273.0	23.80	-21.60	14.40	220.96	236.449
312.0	23.80	-8.45	14.40	218.92	231.488
351.0	23.80	.29	14.40	217.31	227.756
390.0	23.80	3.97	14.40	216.30	225.769
429.0	23.80	4.45	14.40	215.82	224.810
468.0	23.80	3.42	14.40	215.71	224.535
507.0	23.80	2.04	14.40	215.78	224.555
546.0	23.80	.91	14.40	215.92	224.875
585.0	23.80	.21	14.40	216.04	225.100
624.0	23.80	-.11	14.40	216.12	225.262
663.0	23.80	-.16	14.40	216.16	225.346
702.0	23.80	-.12	14.40	216.17	225.362
741.0	23.80	-.04	14.40	216.16	225.331
780.0	23.80	.00	14.40	216.14	225.302

PILE # 6 /SOIL LOADS AND DEFORMATIONS AT TIME =   .93586SECONDS

DEPTH BELOW M.L. (IN)	SOIL MODULUS (K/SQ IN)	SOIL RESISTANCE		PILE 6 DEFL.		PILE 6 F. AND V	
		ALLOW. (K/IN)	ACTUAL (K/IN)	DEFL (IN)	SLOPE (RAD)	MOMENT (IN-K)	SHEAR (K)
TOP 0	.00	.0	.0	.000	.000	0.	1708.9
.0	.00	.0	.0	.000	.000	0.	1708.9
39.0	23.40	273.4	.0	.000	.000	0.	1708.9
78.0	46.80	546.9	.0	.000	.000	0.	1708.9
117.0	70.20	820.3	.0	.000	.000	0.	1708.9
156.0	93.60	1093.7	.0	.000	.000	0.	1708.9
195.0	117.00	1367.1	.0	.000	.000	0.	1708.9
234.0	140.40	1640.6	-.0	.000	.000	0.	1708.9
273.0	163.80	1914.0	-.0	-.000	.000	0.	1708.9
312.0	187.20	2187.4	-.0	-.000	-.000	0.	1708.9
351.0	210.60	2460.9	-.0	-.000	-.000	-0.	1708.9
390.0	234.00	2734.3	.0	-.000	-.000	-0.	1708.9
429.0	257.40	3007.7	.0	.000	-.000	-0.	1708.9
468.0	280.20	3281.1	.0	.000	.000	-0.	1708.9
507.0	304.20	3554.6	.0	.000	.000	-0.	1708.9
546.0	327.60	3828.0	.0	.000	.000	-0.	1708.9
585.0	351.00	4101.4	.0	.000	.000	0.	1708.9
624.0	374.40	4374.9	.0	.000	.000	0.	1708.9
663.0	397.80	4648.3	.0	.000	.000	0.	1708.9
702.0	421.20	4921.7	.0	.000	.000	0.	1708.9
741.0	444.60	5195.2	-.0	-.000	.000	0.	1708.9
780.0	468.00	5468.6	-.0	-.000	.000	0.	1708.9

DOLPHIN/SOIL LOADS AND DEFORMATIONS AT TIME =   .93586 SECONDS

DEPTH BELOW M.L. (IN)	BENDING		SHEAR		COMBINED STRESS RATIO
	ALLOWABLE (KSI)	ACTUAL (KSI)	ALLOWABLE (KSI)	ACTUAL (KSI)	
.0	23.80	.00	14.40	199.11	191.19
39.0	23.80	.00	14.40	199.11	191.19
78.0	23.80	.00	14.40	199.11	191.19
117.0	23.80	.00	14.40	199.11	191.19
156.0	23.80	.00	14.40	199.11	191.19
195.0	23.80	.00	14.40	199.11	191.19
234.0	23.80	.00	14.40	199.11	191.19
273.0	23.80	.00	14.40	199.11	191.19
312.0	23.80	.00	14.40	199.11	191.19
351.0	23.80	-.00	14.40	199.11	191.19
390.0	23.80	-.00	14.40	199.11	191.19
429.0	23.80	-.00	14.40	199.11	191.19
468.0	23.80	-.00	14.40	199.11	191.19
507.0	23.80	-.00	14.40	199.11	191.19
546.0	23.80	-.00	14.40	199.11	191.19
585.0	23.80	-.00	14.40	199.11	191.19
624.0	23.80	.00	14.40	199.11	191.19
663.0	23.80	.00	14.40	199.11	191.19
702.0	23.80	.00	14.40	199.11	191.19
741.0	23.80	.00	14.40	199.11	191.19
780.0	23.80	.00	14.40	199.11	191.19

PILE # 7 /SOIL LOADS AND DEFORMATIONS AT TIME =   .93586SECONDS

DEPTH BELOW M.L. (IN)	SOIL MODULUS (K/SQ IN)	SOIL RESISTANCE ALLOW. (K/IN)	ACTUAL (K/IN)	PILE 7 DEFL. DEFL. (IN)	SLOPE (RAD)	PILE 7 M AND V MOMENT (IN-K)	SHEAR (K)
TOP .0	.00	.0	.0	3.509	.009	0.	1706.9
.0	.00	.0	.0	.083	.001	671.	1695.8
39.0	23.40	273.4	1.4	.059	.001	4691.	1652.3
78.0	46.80	546.9	1.8	.038	.000	8411.	1598.2
117.0	70.20	820.3	1.4	.020	.000	10811.	1534.4
156.0	93.60	1093.7	.8	.008	.000	9706.	1503.4
195.0	117.00	1367.1	.6	.001	.000	7394.	1495.7
234.0	140.40	1640.6	-.5	-.002	.000	4780.	1504.5
273.0	163.80	1914.0	-.5	-.003	.000	2511.	1521.3
312.0	187.20	2187.4	-.5	-.002	-.000	899.	1536.8
351.0	210.60	2460.9	-.4	-.002	-.000	-31.	1552.7
390.0	234.00	2734.3	-.2	-.001	-.000	-422.	1561.4
429.0	257.40	3007.7	-.1	-.000	-.000	-474.	1565.5
468.0	280.80	3281.1	-.0	-.000	-.000	-364.	1566.4
507.0	304.20	3554.6	-.0	.000	-.000	-218.	1565.8
546.0	327.60	3828.0	.0	.000	-.000	-97.	1564.6
585.0	351.00	4101.4	.0	.000	.000	-22.	1563.6
624.0	374.40	4374.9	.0	.000	.000	12.	1562.9
663.0	397.80	4648.3	.0	.000	.000	19.	1562.5
702.0	421.20	4921.7	.0	.000	.000	13.	1562.5
741.0	444.60	5195.2	-.0	-.000	.000	4.	1562.6
780.0	468.00	5468.6	-.0	-.000	.000	0.	1562.7

DOLPHIN/SOIL LOADS AND DEFORMATIONS AT TIME =   .93586 SECONDS

DEPTH BELOW M.L. (IN)	BENDING ALLOWABLE (KSI)	ACTUAL (KSI)	SHEAR ALLOWABLE (KSI)	ACTUAL (KSI)	COMBINED STRESS RATIO
.0	23.80	9.13	14.40	198.06	189.565
39.0	23.80	44.06	14.40	192.53	180.605
78.0	23.80	79.04	14.40	185.05	166.457
117.0	23.80	101.59	14.40	178.78	158.408
156.0	23.80	91.21	14.40	175.17	151.816
195.0	23.80	69.48	14.40	174.27	149.376
234.0	23.80	44.92	14.40	175.30	150.089
273.0	23.80	23.60	14.40	177.26	152.525
312.0	23.80	8.45	14.40	179.10	155.590
351.0	23.80	-.29	14.40	180.51	157.850
390.0	23.80	-3.97	14.40	181.93	159.776
429.0	23.80	-4.45	14.40	182.41	160.442
468.0	23.80	-3.42	14.40	182.52	160.797
507.0	23.80	-2.04	14.40	182.44	160.601
546.0	23.80	-.91	14.40	182.30	160.311
585.0	23.80	-.21	14.40	182.18	160.068
624.0	23.80	.11	14.40	182.10	159.824
663.0	23.80	.18	14.40	182.06	159.835
702.0	23.80	.12	14.40	182.05	159.841
741.0	23.80	.04	14.40	182.07	159.861
780.0	23.80	.00	14.40	182.08	159.862

PILE # 6 /SOIL LOADS AND DEFORMATIONS AT TIME = .93586 SECONDS

DEPTH BELOW M.L. (IN)	SOIL MODULUS (K/SQ IN)	SOIL RESISTANCE		PILE 6 DEFL.		PILE 6 M AND V	
		ALLOW. (K/IN)	ACTUAL (K/IN)	DEFL. (IN)	SLOPE (RAD)	MOMENT (IN-K)	SHEAR (K)
TOP	.00	.0	.0	3.514	.009	0.	1706.9
.0	.00	.0	.0	.084	.001	541.	1696.7
39.0	23.40	273.4	1.4	.060	.001	4421.	1651.5
78.0	46.80	546.9	1.8	.038	.001	8301.	1556.0
117.0	70.20	820.3	1.8	.021	.000	10838.	1520.9
156.0	93.60	1093.7	.8	.009	.000	9792.	1498.9
195.0	117.00	1367.1	.2	.002	.000	7496.	1490.4
234.0	140.40	1640.6	-.3	-.002	.000	4870.	1498.9
273.0	163.80	1914.0	-.6	-.003	.000	2577.	1515.7
312.0	187.20	2187.4	-.5	-.003	-.000	938.	1533.3
351.0	210.60	2460.9	-.4	-.002	-.000	-14.	1547.4
390.0	234.00	2734.3	-.2	-.001	-.000	-418.	1556.2
429.0	257.40	3007.7	-.1	-.000	-.000	-476.	1560.5
468.0	280.80	3281.1	-.0	-.000	-.000	-369.	1561.5
507.0	304.20	3554.6	-.0	-.000	-.000	-222.	1560.9
546.0	327.60	3828.0	.0	.000	-.000	-100.	1559.7
585.0	351.00	4101.4	.0	.000	.000	-23.	1558.6
624.0	374.40	4374.9	.0	.000	.000	8.	1557.9
663.0	397.80	4648.3	.0	.000	.000	1.	1557.6
702.0	421.20	4921.7	.0	.000	.000	1.	1557.5
741.0	444.60	5195.2	-.0	-.000	.000	4.	1557.6
780.0	468.00	5468.6	-.0	-.000	.000	0.	1557.7

DOLPHIN/SOIL LOADS AND DEFORMATIONS AT TIME = .93586 SECONDS

DEPTH BELOW M.L. (IN)	BENDING		SHEAR		COMBINED STRESS RATIO
	ALLOWABLE (KSI)	ACTUAL (KSI)	ALLOWABLE (KSI)	ACTUAL (KSI)	
.0	23.80	5.08	14.40	196.05	189.765
39.0	23.80	41.54	14.40	192.42	180.508
78.0	23.80	78.00	14.40	194.80	167.975
117.0	23.80	101.84	14.40	178.38	157.726
156.0	23.80	92.02	14.40	174.64	150.955
195.0	23.80	70.44	14.40	173.66	148.350
234.0	23.80	45.76	14.40	174.65	149.024
273.0	23.80	24.21	14.40	176.61	151.411
312.0	23.80	8.81	14.40	178.66	154.303
351.0	23.80	-.13	14.40	180.29	156.767
390.0	23.80	-3.93	14.40	181.33	155.731
429.0	23.80	-4.47	14.40	181.02	159.616
468.0	23.80	-3.47	14.40	181.94	159.766
507.0	23.80	-2.08	14.40	181.67	159.556
546.0	23.80	-.94	14.40	181.73	159.307
585.0	23.80	-.22	14.40	181.61	159.061
624.0	23.80	.11	14.40	181.53	158.913
663.0	23.80	.18	14.40	181.49	158.846
702.0	23.80	.12	14.40	181.48	158.829
741.0	23.80	.04	14.40	181.49	158.848
780.0	23.80	.00	14.40	181.50	158.869

175

MICROCOPY RESOLUTION TEST CHART
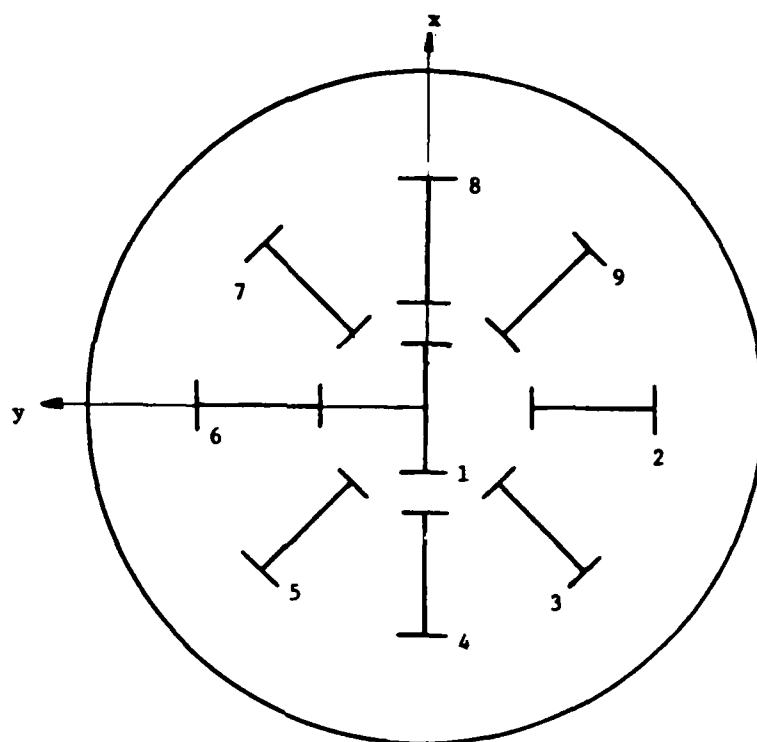
PILE # 9 /SOIL LOADS AND DEFORMATIONS AT TIME = .93586 SECONDS

DEPTH BELOW M.L. (IN)	SOIL MODULUS (K/SQ IN)	SOIL RESISTANCE ALLOW. (K/IN)	ACTUAL (K/IN)	PILE # DEFL. DEFL. (IN)	SLOPE (RAD)	PILE # P AND V MOMENT (IN-K)	SHEAR (K)
TOP.0	.00	.0	.0	3.509	.005	0.	1706.9
39.0	23.40	273.2	1.0	.059	.001	971.	1699.8
78.0	46.80	546.9	1.6	.058	.001	4691.	1652.3
117.0	70.20	820.3	1.4	.038	.000	8411.	1534.4
156.0	93.60	1093.7	.8	.020	.000	6706.	1503.4
195.0	117.00	1367.1	.4	.001	.000	7394.	1495.7
234.0	140.40	1640.0	-.3	-.002	.000	4780.	1504.5
273.0	163.80	1914.0	-.3	-.003	.000	2511.	1531.3
351.0	187.20	2187.4	-.4	-.002	.000	869.	1555.2
351.0	210.60	2460.9	-.2	-.001	.000	-31.	1555.7
390.0	234.00	2734.3	-.1	-.000	.000	-422.	1561.4
429.0	257.40	3007.7	-.1	.000	.000	-474.	1565.5
468.0	280.80	3281.1	-.0	.000	.000	-219.	1565.4
507.0	304.20	3554.6	.0	.000	.000	-97.	1564.6
546.0	327.60	3828.0	.0	.000	.000	-22.	1563.6
585.0	351.00	4101.4	.0	.000	.000	18.	1565.3
624.0	374.40	4374.8	.0	.000	.000	18.	1565.5
663.0	397.80	4648.3	.0	.000	.000	13.	1563.5
702.0	421.20	4921.7	.0	.000	.000	4.	1562.6
741.0	444.60	5195.2	-.0	-.000	.000	0.	1562.7
780.0	468.00	5468.6	-.0	-.000	.000	0.	1562.7

DOLPHIN/SOIL LOADS AND DEFORMATIONS AT TIME = .93586 SECONDS

DEPTH BELOW M.L. (IN)	BENDING ALLOWABLE (KSI)	ACTUAL (KSI)	SHEAR ALLOWABLE (KSI)	ACTUAL (KSI)	COMBINED STRESS RATIO
39.0	23.80	9.13	14.40	198.06	186.565
78.0	23.80	44.08	14.40	192.53	160.605
78.0	23.80	79.04	14.40	185.05	168.457
117.0	23.80	101.59	14.40	178.78	158.408
156.0	23.80	91.21	14.40	175.17	151.813
195.0	23.80	69.46	14.40	174.57	149.379
234.0	23.80	44.92	14.40	175.50	150.029
273.0	23.80	21.60	14.40	177.26	152.525
312.0	23.80	5.45	14.40	179.50	155.493
351.0	23.80	-1.29	14.40	180.61	157.450
390.0	23.80	-3.97	14.40	181.93	159.779
429.0	23.80	-4.45	14.40	182.41	160.642
468.0	23.80	-3.42	14.40	182.52	160.797
507.0	23.80	-2.04	14.40	182.44	160.601
546.0	23.80	-.91	14.40	182.30	160.313
585.0	23.80	-.21	14.40	182.18	160.068
624.0	23.80	.11	14.40	182.10	159.924
663.0	23.80	.18	14.40	182.06	159.856
702.0	23.80	.12	14.40	182.05	159.841
741.0	23.80	.04	14.40	182.07	159.861
780.0	23.80	.00	14.40	182.08	159.862

TABLE 4   PAGE   92

OUTPUT OF DYNAMIC DATA AT THE POINT OF IMPACT

STEP NO	TIME (SEC)	DEFL (IN)	VELOCITY (IN/SEC)	ACCELERATION (IN/SEC/SEC)	FORCE (K)	SPRING K (K/IN)
1	.0000	.00	6.48	.00	1.00	1046.11
2	.1170	.75	6.33	-2.53	366.46	487.04
3	.2340	1.47	5.90	-4.94	716.20	487.04
4	.3509	2.12	5.19	-7.12	1033.39	487.04
5	.4679	2.60	4.25	-8.98	1303.86	487.04
6	.5849	3.11	3.11	-10.44	1513.60	487.04
7	.7019	3.40	1.84	-11.41	1655.30	487.04
8	.8189	3.53	-.47	-11.87	1721.33	487.04
9	.9359	3.51	-.91	-11.78	1708.86	487.04

OUTPUT OF KINETIC AND POTENTIAL ENERGY FOR SYSTEM

STEP NO	TIME (SEC.)	KINETIC ENERGY (IN-K)	POTENTIAL ENERGY (IN-K)	TOTAL PE + KE (IN--K)
1	.0000	3046.	0.	3046.
2	.1170	2909.	138.	3047.
3	.2340	2511.	537.	3049.
4	.3509	1955.	1096.	3051.
5	.4679	1309.	1744.	3054.
6	.5849	703.	2353.	3056.
7	.7019	244.	2813.	3058.
8	.8189	16.	3042.	3058.

```
              TOTAL KINETIC ENERGY OF SHIP =       3046. K-IN
    TOTAL POTENTIAL ENERGY OF DOLPHIN =            3042. K-IN
                              ERROR =              .14 PERCENT
```

```
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
•••••                                                      •••••
•••••  MAXIMUM DEFLECTION AT ML =         .084 INCHES      •••••
•••••                                                      •••••
••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
```

                    FACTOR OF SAFETY =   180.016

BASIC PROGRAM PARAMETERS

```
              WEIGHT OF SHIP =   12500.00 TONS  (  28000.00 KIPS)
            VELOCITY OF SHIP =      .32 KNOTS              6.48 IPS)
   LENGTH OF DOLPHIN BELOW ML =     60.00 FEET
   LENGTH OF DOLPHIN ABOVE ML =     30.00 FEET
                MASS OF SHIP  =      72.53 KIPS/IN/SEC/SEC
    ANGLE OF PASSIVE FAILURE  =   45.00 DEGREES
            DEPTH CORRECTION  =        .00 FEET
          DISSIPATION FACTOR  =      .5000
           ALLOWABLE STRAIN   =      .03000 IN/IN
```

179
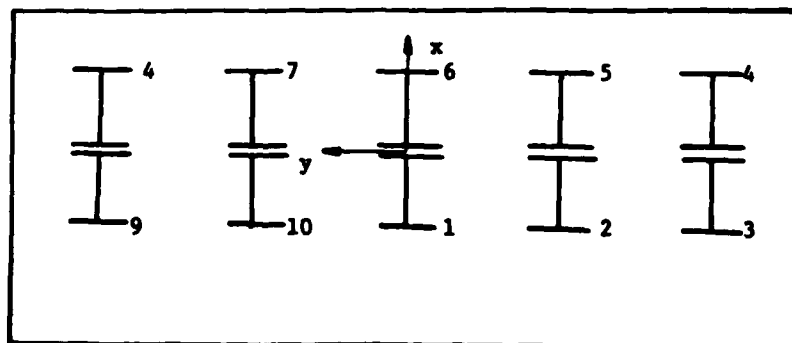
TABLE 5   PAGE 32

PILE # 1 /SOIL LOADS AND DEFORMATIONS AT TIME = .43897SECONDS

DEPTH BELOW M.L. (IN)	SOIL MODULUS (K/SQ IN)	SOIL RESISTANCE ALLOW. (K/IN)	SOIL RESISTANCE ACTUAL (K/IN)	PILE 1 DEFL. DEFL (IN)	PILE 1 DEFL. SLOPE (RAD)	PILE 1 M AND V MOMENT (IN-K)	PILE 1 M AND V SHEAR (K)
TOP	.00	.0	.0	1.327	.005	0.	1984.5
.0	.00	.0	.0	.102	.001	338.	1974.8
36.0	21.60	233.0	1.6	.075	.001	5007.	1922.8
72.0	43.20	465.0	2.6	.050	.001	9677.	1849.5
108.0	64.80	698.9	1.9	.030	.000	12992.	1782.5
144.0	86.40	931.	1.3	.015	.000	12417.	1737.7
180.0	108.00	1164.	.8	.005	.000	10230.	1718.4
216.0	129.60	1397.7	.1	-.001	.000	7349.	1720.3
252.0	151.20	1630.7	-.5	-.003	.000	4535.	1755.3
288.0	172.80	1863.6	-.6	-.003	-.000	2259.	1755.0
324.0	194.40	2096.6	-.5	-.003	-.000	703.	1774.0
360.0	216.00	2329.6	-.4	-.002	-.000	-176.	1788.2
396.0	237.60	2562.5	-.2	-.001	-.000	-535.	1797.3
432.0	259.20	2795.5	-.1	-.000	-.000	-569.	1801.0
468.0	280.80	3028.4	.0	-.000	-.000	-446.	1803.0
504.0	302.40	3261.4	.0	-.000	-.000	-281.	1802.0
540.0	324.00	3494.3	.0	-.000	-.000	-141.	1801.0
576.0	345.60	3727.3	.0	.000	-.000	-48.	1799.7
612.0	367.20	3960.3	.0	.000	.000	-2.	1798.8
648.0	388.80	4193.2	.0	.000	.000	10.	1798.5
684.0	410.40	4426.2	-.0	.000	.000	5.	1798.5
720.0	432.00	4659.1	-.0	-.000	.000	0.	1798.4

DOLPHIN/SOIL LOADS AND DEFORMATIONS AT TIME = .43897 SECONDS

DEPTH BELOW M.L. (IN)	BENDING ALLOWABLE (KSI)	BENDING ACTUAL (KSI)	SHEAR ALLOWABLE (KSI)	SHEAR ACTUAL (KSI)	COMBINED STRESS RATIO
.0	23.80	3.18	14.40	230.10	255.465
36.0	23.80	47.06	14.40	226.04	244.030
72.0	23.80	90.93	14.40	213.47	227.718
108.0	23.80	122.09	14.40	207.69	213.150
144.0	23.80	116.69	14.40	202.47	202.599
180.0	23.80	96.13	14.40	200.22	197.373
216.0	23.80	69.06	14.40	200.44	196.655
252.0	23.80	42.61	14.40	202.19	198.931
288.0	23.80	21.23	14.40	204.51	202.594
324.0	23.80	6.60	14.40	205.31	206.335
360.0	23.80	-1.65	14.40	206.39	209.486
396.0	23.80	-5.03	14.40	208.34	211.732
432.0	23.80	-5.35	14.40	209.95	212.797
468.0	23.80	-4.16	14.40	210.08	213.014
504.0	23.80	-2.64	14.40	210.00	212.793
540.0	23.80	-1.33	14.40	209.85	212.423
576.0	23.80	-.46	14.40	209.79	212.084
612.0	23.80	-.02	14.40	209.79	211.956
648.0	23.80	.10	14.40	209.83	211.730
684.0	23.80	.05	14.40	209.83	211.763
720.0	23.80	.00	14.40	209.35	211.763

PILE # 2 /SOIL LOADS AND DEFORMATIONS AT TIME =   .43897 SECONDS

DEPTH BELOW M.L. (IN)	SOIL MODULUS (K/SQ IN)	SOIL RESISTANCE ALLOW. (K/IN)	ACTUAL (K/IN)	PILE 2 DEFL. DEFL (IN)	SLOPE (RAD)	PILE 2 M AND V MOMENT (IN-K)	SHEAR (K)
TOP .0	.00	.0	.0	1.327	.005	0.	1984.5
36.0	.00	.0	.0	.102	.001	337.	1974.8
72.0	21.60	233.0	1.0	.075	.001	5006.	1922.8
108.0	43.20	465.9	2.2	.050	.001	9674.	1849.3
144.0	64.80	698.9	1.9	.030	.000	12969.	1782.5
180.0	86.40	931.8	1.5	.013	.000	15415.	1737.7
216.0	108.00	1164.8	.5	.003	.000	10228.	1718.5
252.0	129.60	1397.7	-.1	-.001	.000	7347.	1720.5
288.0	151.20	1630.7	-.5	-.003	.000	4534.	1735.3
324.0	172.80	1863.6	-.6	-.003	-.000	2259.	1755.2
360.0	194.40	2096.6	-.5	-.003	-.000	502.	1774.3
396.0	216.00	2329.6	-.4	-.002	-.000	-176.	1788.5
432.0	237.60	2562.5	-.2	-.001	-.000	-535.	1797.6
468.0	259.20	2795.5	-.0	-.000	-.000	-569.	1801.5
504.0	280.80	3028.4	-.0	.000	-.000	-445.	1803.0
540.0	302.40	3261.4	.0	.000	-.000	-281.	1802.4
576.0	324.00	3494.3	.0	.000	.000	-141.	1801.0
612.0	345.60	3727.3	.0	.000	.000	-48.	1799.4
648.0	367.20	3960.3	.0	.000	.000	-2.	1798.8
684.0	388.80	4193.2	.0	.000	.000	10.	1798.3
720.0	410.40	4426.2	.0	.000	.000	5.	1798.5
	432.00	4659.1	-.0	-.000	.000	0.	1798.5

DOLPHIN/SOIL LOADS AND DEFORMATIONS AT TIME =   .43897 SECONDS

DEPTH BELOW M.L. (IN)	BENDING ALLOWABLE (KSI)	ACTUAL (KSI)	SHEAR ALLOWABLE (KSI)	ACTUAL (KSI)	COMBINED STRESS RATIO
.0	23.80	3.17	14.40	230.10	255.465
36.0	23.80	67.04	14.40	224.04	244.032
72.0	23.80	90.91	14.40	215.47	227.724
108.0	23.80	122.06	14.40	207.69	213.159
144.0	23.80	116.66	14.40	202.48	202.609
180.0	23.80	96.11	14.40	200.23	197.384
216.0	23.80	69.04	14.40	200.45	196.666
252.0	23.80	42.60	14.40	202.19	198.942
288.0	23.80	21.23	14.40	204.52	202.603
324.0	23.80	6.60	14.40	206.39	206.144
360.0	23.80	-1.65	14.40	208.39	208.494
396.0	23.80	-5.03	14.40	209.44	211.760
432.0	23.80	-5.33	14.40	209.85	212.805
468.0	23.80	-4.19	14.40	210.09	213.022
504.0	23.80	-2.63	14.40	210.01	212.866
540.0	23.80	-1.32	14.40	209.85	212.432
576.0	23.80	-.46	14.40	209.70	212.091
612.0	23.80	-.02	14.40	209.54	211.745
648.0	23.80	.10	14.40	209.54	211.738
684.0	23.80	.05	14.40	209.55	211.771
720.0	23.80	.00	14.40	209.55	

PILE # 3 /SOIL LOADS AND DEFORMATIONS AT TIME = .43897 SECONDS

DEPTH BELOW M.L. (IN)	SOIL MODULUS (K/SQ IN)	SOIL RESISTANCE		PILE 3 DEFL.		PILE 3 M AND V	
		ALLOW. (K/IN)	ACTUAL (K/IN)	DEFL. (IN)	SLOPE (RAD)	MOMENT (IN-K)	SHEAR (K)
TOP -0	.00	.0	.0	.672	.002	0.	1984.5
36.0	.00	.0	.0	.058	.000	21.	1979.6
72.0	21.60	233.0	.8	.038	.000	2405.	1953.4
108.0	43.20	465.9	1.1	.025	.000	4782.	1916.3
144.0	64.80	698.9	1.0	.015	.000	6420.	1882.8
180.0	86.40	931.8	.6	.007	.000	8220.	1856.8
216.0	108.00	1164.8	.3	.002	.000	5143.	1849.9
252.0	129.60	1397.7	-.0	-.000	.000	3764.	1850.7
288.0	151.20	1630.7	-.2	-.001	.000	2292.	1858.1
324.0	172.80	1863.6	-.3	-.002	-.000	114.	1859.0
360.0	194.40	2096.6	-.3	-.001	-.000	362.	1859.8
396.0	216.00	2329.6	-.2	-.001	-.000	-83.	1884.8
432.0	237.60	2562.5	-.1	-.001	-.000	-266.	1889.4
468.0	259.20	2795.5	-.1	-.000	-.000	-285.	1891.2
504.0	280.80	3028.4	-.0	-.000	-.000	-224.	1892.1
540.0	302.40	3261.4	-.0	-.000	-.000	-142.	1891.8
576.0	324.00	3494.3	-.0	-.000	-.000	-71.	1891.2
612.0	345.60	3727.3	.0	.000	-.000	-25.	1890.7
648.0	367.20	3960.3	.0	.000	.000	-4.	1889.9
684.0	388.80	4193.2	.0	.000	.000	0.	1889.9
720.0	410.40	4426.2	.0	.000	.000	0.	1889.9
720.0	432.00	4659.1	-.0	-.000	.000	0.	1889.9

DOLPHIN/SOIL LOADS AND DEFORMATIONS AT TIME = .43897 SECONDS

DEPTH BELOW M.L. (IN)	BENDING		SHEAR		COMBINED STRESS RATIO
	ALLOWABLE (KSI)	ACTUAL (KSI)	ALLOWABLE (KSI)	ACTUAL (KSI)	
.0	23.80	.20	14.40	230.06	256.593
36.0	23.80	22.60	14.40	227.61	250.785
72.0	23.80	45.00	14.40	223.29	242.339
108.0	23.80	60.99	14.40	216.70	234.401
144.0	23.80	58.51	14.40	215.55	228.043
180.0	23.80	48.33	14.40	215.55	225.919
216.0	23.80	34.80	14.40	215.48	215.907
252.0	23.80	21.54	14.40	216.50	216.620
288.0	23.80	10.78	14.40	217.99	218.420
324.0	23.80	3.40	14.40	218.90	219.420
360.0	23.80	.78	14.40	219.81	219.620
396.0	23.80	-2.50	14.40	220.40	224.620
432.0	23.80	-2.65	14.40	220.40	224.020
468.0	23.80	-2.10	14.40	220.40	224.620
504.0	23.80	-1.33	14.40	220.43	224.590
540.0	23.80	-.67	14.40	220.36	224.090
576.0	23.80	-.23	14.40	220.20	224.020
612.0	23.80	.02	14.40	220.00	223.020
648.0	23.80	.05	14.40	220.00	223.020
684.0	23.80	.03	14.40	220.00	223.020
720.0	23.80	.00	14.40	220.21	233.064

PILE # 4 /SOIL LOADS AND DEFORMATIONS AT TIME = .43897 SECONDS

DEPTH BELOW M.L. (IN)	SOIL MODULUS (K/SQ IN)	SOIL RESISTANCE ALLOW. (K/IN)	ACTUAL (K/IN)	PILE 4 DEFL. DEFL. (IN)	SLOPE (RAD)	PILE 4 M AND V MOMENT (IN-K)	SHEAR (K)	D
TOP	.00	.0	.0	1.506	.005	0.	1984.5	
.0	.00	.0	.0	.117	.001	748.	1973.4	
36.0	21.60	233.0	1.9	.086	.001	5999.	1916.0	1
72.0	43.20	465.9	2.5	.057	.001	11250.	1830.3	1
108.0	64.80	698.9	2.2	.034	.001	14957.	1754.4	2
144.0	86.40	931.8	1.4	.016	.000	14240.	1703.7	2
180.0	108.00	1164.8	.6	.005	.000	11698.	1682.2	2
216.0	129.60	1397.7	-.1	-.001	.000	8382.	1684.8	3
252.0	151.20	1630.7	-.5	-.003	.000	5156.	1702.1	3
288.0	172.80	1863.6	-.7	-.004	-.000	2557.	1725.2	4
324.0	194.40	2096.6	-.6	-.003	-.000	783.	1746.7	4
360.0	216.00	2329.6	-.5	-.002	-.000	-214.	1763.1	5
396.0	237.60	2562.5	-.3	-.001	-.000	-619.	1773.4	5
432.0	259.20	2795.5	-.1	-.000	-.000	-653.	1778.3	5
468.0	280.80	3028.4	-.0	-.000	-.000	-509.	1779.0	6
504.0	302.40	3261.4	.0	-.000	-.000	-321.	1778.6	6
540.0	324.00	3494.3	.0	.000	-.000	-160.	1777.3	6
576.0	345.60	3727.3	.0	.000	.000	-54.	1775.8	6
612.0	367.20	3960.2	.0	.000	.000	-2.	1774.7	6
648.0	388.80	4193.2	.0	.000	.000	12.	1774.2	7
684.0	410.40	4426.2	.0	.000	.000	8.	1774.3	7
720.0	432.00	4659.1	-.0	-.000	.000	0.	1774.3	

DOLPHIN/SOIL LOADS AND DEFORMATIONS AT TIME = .43897 SECONDS

DEPTH BELOW M.L. (IN)	BENDING ALLOWABLE (KSI)	ACTUAL (KSI)	SHEAR ALLOWABLE (KSI)	ACTUAL (KSI)	COMBINED STRESS RATIO
.0	23.80	7.03	14.40	229.94	255.269
36.0	23.80	56.38	14.40	223.02	242.226
72.0	23.80	105.72	14.40	213.26	223.769
108.0	23.80	140.55	14.40	204.42	207.427
144.0	23.80	133.81	14.40	198.52	195.672
180.0	23.80	109.93	14.40	196.01	189.896
216.0	23.80	78.76	14.40	196.30	189.145
252.0	23.80	48.46	14.40	198.33	191.725
288.0	23.80	24.03	14.40	201.00	195.847
324.0	23.80	7.36	14.40	203.52	200.053
360.0	23.80	-2.01	14.40	205.43	203.606
396.0	23.80	-5.81	14.40	206.63	206.148
432.0	23.80	-6.14	14.40	207.21	207.313
468.0	23.80	-4.79	14.40	207.55	207.547
504.0	23.80	-3.01	14.40	207.26	207.290
540.0	23.80	-1.50	14.40	207.08	206.871
576.0	23.80	-.51	14.40	206.91	206.485
612.0	23.80	-.02	14.40	206.79	206.217
648.0	23.80	.11	14.40	206.72	206.094
684.0	23.80	.08	14.40	206.72	206.088
720.0	23.80	.00	14.40	206.74	206.126

PILE # 5 /SOIL LOADS AND DEFORMATIONS AT TIME = .43897SECONDS

DEPTH BELOW M.L. (IN)	SOIL MODULUS (K/SQ IN)	SOIL RESISTANCE ALLOW. (K/IN)	ACTUAL (K/IN)	PILE 5 DEFL. DEFL (IN)	SLOPE (RAD)	PILE 5 M AND V MOMENT (IN-K)	SHEAR (K)
TOP	.00	.0	.0	1.506	.005	0.	1984.5
.0	.00	.0	.0	.117	.001	749.	1973.4
36.0	21.60	233.0	1.9	.086	.001	6001.	1912.0
72.0	43.20	465.9	2.5	.057	.001	11253.	1830.2
108.0	64.80	698.9	2.4	.034	.001	14961.	1754.4
144.0	86.40	931.8	1.6	.016	.000	14243.	1703.7
180.0	108.00	1164.8	.5	.005	.000	11701.	1682.2
216.0	129.60	1397.7	-.5	-.001	.000	8383.	1684.7
252.0	151.20	1630.7	-.5	-.003	-.000	5157.	1702.1
288.0	172.80	1863.6	-.7	-.004	-.000	2557.	1725.0
324.0	194.40	2096.6	-.6	-.003	-.000	783.	1748.6
360.0	216.00	2329.6	-.5	-.002	-.000	-214.	1763.1
396.0	237.60	2562.5	-.3	-.001	-.000	-619.	1773.3
432.0	259.20	2795.5	-.1	-.000	-.000	-653.	1778.3
468.0	280.80	3028.4	-.0	-.000	-.000	-509.	1779.6
504.0	302.40	3261.4	.0	-.000	-.000	-321.	1778.8
540.0	324.00	3494.3	.0	.000	-.000	-160.	1777.2
576.0	345.60	3727.3	.0	.000	.000	-54.	1775.9
612.0	367.20	3960.3	.0	.000	.000	-2.	1775.2
648.0	388.80	4193.2	.0	.000	.000	12.	1774.1
684.0	410.40	4426.2	.0	.000	.000	6.	1774.1
720.0	432.00	4659.1	-.0	-.000	.000	0.	1774.3

DOLPHIN/SOIL LOADS AND DEFORMATIONS AT TIME = .43897 SECONDS

DEPTH BELOW M.L. (IN)	BENDING ALLOWABLE (KSI)	ACTUAL (KSI)	SHEAR ALLOWABLE (KSI)	ACTUAL (KSI)	COMBINED STRESS RATIO
.0	23.80	7.04	14.40	229.94	255.269
36.0	23.80	56.40	14.40	223.02	242.224
72.0	23.80	105.75	14.40	213.26	223.763
108.0	23.80	140.59	14.40	204.41	207.418
144.0	23.80	133.84	14.40	198.51	195.661
180.0	23.80	109.95	14.40	196.00	189.885
216.0	23.80	78.78	14.40	196.30	189.133
252.0	23.80	48.46	14.40	198.32	191.714
288.0	23.80	24.03	14.40	201.00	195.837
324.0	23.80	7.36	14.40	203.51	200.043
360.0	23.80	-2.01	14.40	205.43	203.597
396.0	23.80	-5.82	14.40	206.63	206.139
432.0	23.80	-6.14	14.40	207.20	207.305
468.0	23.80	-4.79	14.40	207.35	207.539
504.0	23.80	-3.01	14.40	207.25	207.282
540.0	23.80	-1.50	14.40	207.08	206.863
576.0	23.80	-.51	14.40	206.91	206.477
612.0	23.80	-.02	14.40	206.78	206.208
648.0	23.80	.11	14.40	206.72	206.086
684.0	23.80	.06	14.40	206.72	206.080
720.0	23.80	.00	14.40	206.74	206.118

PILE # 6 /SOIL LOADS AND DEFORMATIONS AT TIME = .43897SECONDS

DEPTH BELOW M.L. (IN)	SOIL MODULUS (K/SQ IN)	SOIL RESISTANCE ALLOW. (K/IN)	ACTUAL (K/IN)	PILE 6 DEFL. DEFL (IN)	SLOPE (RAD)	PILE 6 M AND V MOMENT (IN-K)	SHEAR (K)
TOP	.00	.0	.0	1.507	.005	0.	1984.5
.0	.00	.0	.0	.117	.001	751.	1973.4
36.0	21.60	233.0	1.9	.086	.001	6003.	1914.0
72.0	43.20	465.9	1.5	.057	.001	11256.	1830.2
108.0	64.80	698.9	2.2	.034	.001	14964.	1754.3
144.0	86.40	931.8	1.4	.016	.000	14246.	1703.6
180.0	108.00	1165.8	.6	.005	.000	11703.	1682.1
216.0	129.60	1397.7	-.1	-.001	.000	8385.	1684.6
252.0	151.20	1630.7	-.5	-.003	-.000	5158.	1702.0
288.0	172.80	1863.6	-.7	-.004	-.000	2556.	1725.0
324.0	194.40	2096.6	-.6	-.003	-.000	783.	1746.6
360.0	216.00	2329.6	-.5	-.002	-.000	-214.	1763.0
396.0	237.60	2562.5	-.3	-.001	-.000	-619.	1773.3
432.0	259.20	2795.5	-.1	-.000	-.000	-653.	1778.3
468.0	280.80	3028.4	-.0	-.000	-.000	-510.	1779.5
504.0	302.40	3261.4	.0	.000	-.000	-321.	1778.7
540.0	324.00	3494.3	.0	.000	-.000	-160.	1777.2
576.0	345.60	3727.3	.0	.000	.000	-54.	1775.7
612.0	367.20	3960.2	.0	.000	.000	-5.	1774.7
648.0	388.80	4193.2	.0	.000	.000	12.	1774.1
684.0	410.40	4426.2	-.0	-.000	.000	6.	1774.1
720.0	432.00	4659.1	-.0	-.000	.000	0.	1774.3

DOLPHIN/SOIL LOADS AND DEFORMATIONS AT TIME = .43897 SECONDS

| DEPTH BELOW M.L. (IN)	BENDING ALLOWABLE (KSI)	ACTUAL (KSI)	SHEAR ALLOWABLE (KSI)	ACTUAL (KSI)	COMBINED STRESS RATIO
.0	23.80	7.05	14.40	229.94	255.269
36.0	23.80	56.41	14.40	223.01	242.221
72.0	23.80	105.77	14.40	213.25	223.756
108.0	23.80	140.62	14.40	204.41	207.409
144.0	23.80	133.87	14.40	198.50	195.650
180.0	23.80	109.97	14.40	195.99	189.873
216.0	23.80	78.80	14.40	196.89	189.122
252.0	23.80	48.47	14.40	198.32	191.703
288.0	23.80	24.03	14.40	200.99	195.826
324.0	23.80	7.36	14.40	203.51	200.034
360.0	23.80	-2.01	14.40	205.42	203.585
396.0	23.80	-5.82	14.40	206.62	206.131
432.0	23.80	-6.14	14.40	207.20	207.297
468.0	23.80	-4.79	14.40	207.36	207.331
504.0	23.80	-3.01	14.40	207.25	207.273
540.0	23.80	-1.50	14.40	207.08	206.854
576.0	23.80	-.51	14.40	206.90	206.468
612.0	23.80	-.02	14.40	206.78	206.200
648.0	23.80	.11	14.40	206.72	206.077
684.0	23.80	.06	14.40	206.71	206.071
720.0	23.80	.00	14.40	206.73	206.109

PILE # 7 /SOIL LOADS AND DEFORMATIONS AT TIME = .43897 SECONDS

DEPTH BELOW M.L. (IN)	SOIL MODULUS (K/SQ IN)	SOIL RESISTANCE ALLOW. (K/IN)	SOIL RESISTANCE ACTUAL (K/IN)	PILE 7 DEFL. DEFL. (IN)	PILE 7 DEFL. SLOPE (RAD)	PILE 7 M AND V MOMENT (IN-K)	PILE 7 M AND V SHEAR (K)
TOP .0	.00	.0	.0	1.507	.005	0.	1984.5
.0	.00	.0	.0	.117	.001	752.	1973.4
36.0	21.60	233.0	1.9	.086	.001	6005.	1912.0
72.0	43.20	465.9	2.5	.057	.001	11259.	1830.2
108.0	64.80	698.9	2.2	.034	.001	14668.	1934.5
144.0	86.40	931.8	1.4	.016	.000	14249.	1703.6
180.0	108.00	1164.8	.6	.005	.000	11706.	1682.6
216.0	129.60	1397.7	-.1	-.001	.000	8387.	1684.6
252.0	151.20	1630.7	-.5	-.003	.000	5159.	1702.0
288.0	172.80	1863.6	-.7	-.005	.000	2538.	1724.9
324.0	194.40	2096.6	-.6	-.004	.000	783.	1746.3
360.0	216.00	2329.6	-.5	-.002	.000	-214.	1763.0
396.0	237.60	2562.5	-.3	-.001	.000	-619.	1773.2
432.0	259.20	2795.5	-.1	-.000	.000	-654.	1779.1
468.0	280.80	3028.4	-.0	-.000	-.000	-510.	1778.7
504.0	302.40	3261.4	.0	.000	-.000	-321.	1778.7
540.0	324.00	3494.3	.0	.000	-.000	-160.	1777.2
576.0	345.60	3727.3	.0	.000	.000	-54.	1775.5
612.0	367.20	3960.2	.0	.000	.000	-2.	1774.6
648.0	388.80	4193.2	.0	.000	.000	12.	1774.0
684.0	410.40	4426.2	-.0	.000	.000	8.	1774.1
720.0	432.00	4659.1	-.0	-.000	.000	0.	1774.2

DOLPHIN/SOIL LOADS AND DEFORMATIONS AT TIME = .43897 SECONDS

DEPTH BELOW M.L. (IN)	BENDING ALLOWABLE (KSI)	BENDING ACTUAL (KSI)	SHEAR ALLOWABLE (KSI)	SHEAR ACTUAL (KSI)	COMBINED STRESS RATIO
.0	23.80	7.07	14.40	229.94	255.269
36.0	23.80	56.43	14.40	223.01	242.218
72.0	23.80	105.80	14.40	213.25	223.750
108.0	23.80	140.85	14.40	204.40	207.400
144.0	23.80	133.90	14.40	196.50	195.659
180.0	23.80	110.00	14.40	195.99	189.861
216.0	23.80	78.81	14.40	196.28	189.110
252.0	23.80	48.48	14.40	198.31	191.692
288.0	23.80	24.04	14.40	200.59	195.816
324.0	23.80	7.36	14.40	203.50	200.024
360.0	23.80	-2.01	14.40	205.42	203.579
396.0	23.80	-5.82	14.40	206.62	206.123
432.0	23.80	-6.14	14.40	207.20	207.289
468.0	23.80	-4.79	14.40	207.54	207.523
504.0	23.80	-3.01	14.40	207.25	207.265
540.0	23.80	-1.50	14.40	207.07	206.846
576.0	23.80	-.51	14.40	206.90	206.480
612.0	23.80	-.02	14.40	206.77	206.192
648.0	23.80	.11	14.40	206.71	206.069
684.0	23.80	.06	14.40	206.71	206.063
720.0	23.80	.00	14.40	206.73	206.101

PILE # 8 /SOIL LOADS AND DEFORMATIONS AT TIME = .43897SECONDS

DEPTH BELOW M.L. (IN)	SOIL MODULUS (K/SQ IN)	SOIL RESISTANCE ALLOW. (K/IN)	ACTUAL (K/IN)	PILE 8 DEFL. DEFL (IN)	SLOPE (RAD)	PILE 8 M AND V MOMENT (IN-K)	SHEAR (K)
TOP	.00	.0	.0	1.507	.005	0.	1984.5
.0	.00	.0	.0	.117	.001	753.	1973.4
36.0	21.60	233.0	1.9	.086	.001	6008.	1914.0
72.0	43.20	465.9	2.5	.057	.001	11252.	1830.2
108.0	64.80	698.9	2.2	.054	.001	14971.	1754.2
144.0	86.40	931.8	1.4	.016	.000	14252.	1703.2
180.0	108.00	1164.8	.6	.005	.000	11708.	1682.0
216.0	129.60	1397.7	-.1	-.001	.000	8369.	1694.5
252.0	151.20	1630.7	-.5	-.003	.000	5160.	1701.9
288.0	172.80	1863.6	-.7	-.004	-.000	2559.	1724.9
324.0	194.40	2096.6	-.6	-.003	-.000	783.	1746.5
360.0	216.00	2329.6	-.5	-.002	-.000	-214.	1762.9
396.0	237.60	2562.5	-.3	-.001	-.000	-619.	1773.2
432.0	259.20	2795.5	-.1	-.000	-.000	-654.	1778.2
468.0	280.80	3028.4	-.0	-.000	-.000	-510.	1779.4
504.0	302.40	3261.4	.0	-.000	-.000	-321.	1778.7
540.0	324.00	3494.3	.0	.000	-.000	-160.	1777.1
576.0	345.60	3727.3	.0	.000	.000	-54.	1775.7
612.0	367.20	3960.3	.0	.000	.000	-2.	1775.0
648.0	388.80	4193.2	.0	.000	.000	12.	1774.0
684.0	410.40	4426.2	.0	.000	.000	6.	1774.0
720.0	432.00	4659.1	-.0	-.000	.000	0.	1774.2

DOLPHIN/SOIL LOADS AND DEFORMATIONS AT TIME = .43897 SECONDS

DEPTH BELOW M.L. (IN)	BENDING ALLOWABLE (KSI)	ACTUAL (KSI)	SHEAR ALLOWABLE (KSI)	ACTUAL (KSI)	COMBINED STRESS RATIO
.0	23.80	7.08	14.40	229.94	255.269
36.0	23.80	56.45	14.40	223.01	242.215
72.0	23.80	105.83	14.40	213.25	223.744
108.0	23.80	140.68	14.40	204.40	207.391
144.0	23.80	133.93	14.40	198.49	195.628
180.0	23.80	110.02	14.40	195.98	189.850
216.0	23.80	78.83	14.40	196.28	189.098
252.0	23.80	48.49	14.40	196.50	191.681
288.0	23.80	24.04	14.40	200.98	195.806
324.0	23.80	7.36	14.40	203.50	200.014
360.0	23.80	-2.01	14.40	205.41	203.570
396.0	23.80	-5.82	14.40	206.61	206.114
432.0	23.80	-6.14	14.40	207.19	207.281
468.0	23.80	-4.79	14.40	207.34	207.515
504.0	23.80	-3.01	14.40	207.25	207.257
540.0	23.80	-1.50	14.40	207.07	206.838
576.0	23.80	-.51	14.40	206.89	206.452
612.0	23.80	-.02	14.40	206.77	206.183
648.0	23.80	.11	14.40	206.71	206.060
684.0	23.80	.06	14.40	206.70	206.054
720.0	23.80	.00	14.40	206.73	206.092

PILE # 9 /SOIL LOADS AND DEFORMATIONS AT TIME = .43897SECONDS

DEPTH BELOW M.L. (IN)	SOIL MODULUS (K/SQ IN)	SOIL RESISTANCE ALLOW. (K/IN)	ACTUAL (K/IN)	PILE 9 DEFL. DEFL. (IN)	SLOPE (RAD)	PILE 9 M AND V MOMENT (IN-K)	SHEAR (K)
TOP	.00	.0	.0	-1.154	-.004	0.	1984.3
.0			.0	-.089	-.001	-2100.	1993.0
36.0	21.60	233.0	-1.4	-.065	-.001	-4284.	2038.2
72.0	43.20	465.9	-1.9	-.044	-.001	-8358.	2102.1
108.0	64.80	698.9	-1.7	-.026	-.000	-11255.	2160.2
144.0	86.40	931.8	-1.1	-.013	-.000	-10771.	2199.2
180.0	108.00	1164.8	-.4	-.004	-.000	-8881.	2216.1
216.0	129.60	1397.7	.1	-.001	-.000	-6365.	2214.5
252.0	151.20	1630.7	.4	.003	-.000	-3943.	2201.6
288.0	172.80	1863.6	.5	.003	.000	-1968.	2184.6
324.0	194.40	2096.6	.5	.002	.000	-615.	2167.9
360.0	216.00	2329.5	.4	.002	.000	249.	2155.4
396.0	237.60	2562.5	.2	.001	.000	663.	2147.6
432.0	259.20	2795.5	.1	.000	.000	494.	2143.7
468.0	280.80	3028.4	.0	.000	.000	387.	2142.4
504.0	302.40	3261.4	-.0	-.000	-.000	244.	2143.5
540.0	327.00	3494.3	-.0	-.000	-.000	123.	2144.4
576.0	367.20	3727.3	-.0	-.000	-.000	42.	2146.6
612.0	367.20	3960.3	-.0	-.000	-.000	-0.	2146.6
648.0	388.80	4193.2	-.0	-.000	-.000	-9.	2146.8
684.0	410.40	4426.2	-.0	.000	-.000	-5.	2146.7
720.0	432.00	4659.1	.0	.000	-.000	0.	2146.7

DOLPHIN/SOIL LOADS AND DEFORMATIONS AT TIME = .43897 SECONDS

DEPTH BELOW M.L. (IN)	BENDING ALLOWABLE (KSI)	ACTUAL (KSI)	SHEAR ALLOWABLE (KSI)	ACTUAL (KSI)	COMBINED STRESS RATIO
.0	23.80	-1.97	14.40	232.22	260.145
36.0	23.80	-40.26	14.40	237.49	273.683
72.0	23.80	-78.54	14.40	244.93	292.611
108.0	23.80	-105.77	14.40	251.70	309.963
144.0	23.80	-101.21	14.40	256.25	320.909
180.0	23.80	-63.46	14.40	258.21	325.035
216.0	23.80	-60.00	14.40	258.03	323.607
252.0	23.80	-37.06	14.40	256.52	318.902
288.0	23.80	-18.49	14.40	254.51	313.155
324.0	23.80	-5.78	14.40	252.60	307.960
360.0	23.80	1.40	14.40	251.13	304.234
396.0	23.80	4.35	14.40	250.23	302.143
432.0	23.80	4.64	14.40	249.78	301.083
468.0	23.80	3.63	14.40	249.67	300.764
504.0	23.80	2.30	14.40	249.74	300.868
540.0	23.80	1.15	14.40	249.87	301.142
576.0	23.80	.40	14.40	250.00	301.425
612.0	23.80	.02	14.40	250.09	301.637
648.0	23.80	-.08	14.40	250.14	301.757
684.0	23.80	-.04	14.40	250.14	301.760
720.0	23.80	.00	14.40	250.13	301.721

PILE #10 /SOIL LOADS AND DEFORMATIONS AT TIME = .43897 SECONDS

DEPTH BELOW M.L. (IN)	SOIL MODULUS (K/SQ IN)	SOIL RESISTANCE ALLOW. (K/IN)	SOIL RESISTANCE ACTUAL (K/IN)	PILE 10 DEFL. DEFL. (IN)	PILE 10 DEFL. SLOPE (RAD)	PILE 10 M AND V MOMENT (IN-K)	PILE 10 M AND V SHEAR (K)
TOP	.00	.0	.0	1.327	.005	0.	1984.5
.0	.00	.0	.0	.102	.001	339.	1974.8
36.0	21.60	233.0	1.6	.075	.001	5009.	1922.8
72.0	43.20	465.9	2.2	.050	.001	9679.	1849.2
108.0	64.80	698.9	1.9	.030	.000	12995.	1782.4
144.0	86.40	931.8	1.3	.015	.000	12420.	1737.6
180.0	108.00	1164.8	.5	.005	.000	10252.	1718.4
216.0	129.60	1397.7	-.1	-.001	.000	7350.	1720.2
252.0	151.20	1630.7	-.5	-.003	.000	4535.	1735.2
288.0	172.80	1863.6	-.6	-.003	-.000	2260.	1755.2
324.0	194.40	2096.6	-.5	-.003	-.000	703.	1772.0
360.0	216.00	2329.6	-.4	-.002	-.000	-176.	1788.4
396.0	237.60	2562.5	-.2	-.001	-.000	-535.	1797.6
432.0	259.20	2795.5	-.1	-.000	-.000	-569.	1801.6
468.0	280.80	3028.4	-.0	-.000	-.000	-446.	1803.0
504.0	302.40	3261.4	-.0	-.000	-.000	-281.	1802.5
540.0	324.00	3494.3	.0	.000	.000	-141.	1801.0
576.0	345.60	3727.3	.0	.000	.000	-45.	1799.9
612.0	367.20	3960.2	.0	.000	.000	-7.	1798.8
648.0	388.80	4193.2	.0	.000	.000	10.	1798.6
684.0	410.40	4426.2	.0	.000	.000	5.	1798.3
720.0	432.00	4659.1	-.0	-.000	.000	0.	1798.4

DOLPHIN/SOIL LOADS AND DEFORMATIONS AT TIME = .43897 SECONDS

DEPTH BELOW M.L. (IN)	BENDING ALLOWABLE (KSI)	BENDING ACTUAL (KSI)	SHEAR ALLOWABLE (KSI)	SHEAR ACTUAL (KSI)	COMBINED STRESS RATIO
.0	23.80	3.19	14.40	230.10	255.465
36.0	23.80	47.07	14.40	224.03	244.027
72.0	23.80	90.96	14.40	215.47	227.712
108.0	23.80	122.12	14.40	207.69	213.142
144.0	23.80	116.71	14.40	202.46	202.589
180.0	23.80	96.15	14.40	200.22	197.362
216.0	23.80	69.07	14.40	200.44	196.644
252.0	23.80	42.62	14.40	202.18	198.921
288.0	23.80	21.24	14.40	204.51	202.584
324.0	23.80	6.60	14.40	206.70	206.326
360.0	23.80	-1.65	14.40	208.38	209.678
396.0	23.80	-5.03	14.40	209.44	211.744
432.0	23.80	-5.35	14.40	209.95	212.780
468.0	23.80	-4.19	14.40	210.08	213.007
504.0	23.80	-2.64	14.40	210.00	212.785
540.0	23.80	-1.33	14.40	209.85	212.617
576.0	23.80	-.46	14.40	209.70	212.076
612.0	23.80	-.05	14.40	209.59	211.838
648.0	23.80	.10	14.40	209.53	211.726
684.0	23.80	.05	14.40	209.53	211.722
720.0	23.80	.00	14.40	209.55	211.755

TABLE 6   PAGE   52

OUTPUT OF DYNAMIC DATA AT THE POINT OF IMPACT

STEP NO	TIME (SEC)	DEFL (IN)	VELOCITY (IN/SEC)	ACCELERATION (IN/SEC/SEC)	FORCE (K)	SPRING K (K/IN)
1	.0000	.00	6.48	.00	1.00	596.36
2	.1097	.68	5.71	-14.08	1021.40	1495.47
3	.2195	1.20	3.57	-24.81	1769.22	1495.47
4	.3292	1.44	.59	-29.62	2145.00	1495.47
5	.4390	1.33	-2.54	-27.36	1984.55	1495.47

OUTPUT OF KINETIC AND POTENTIAL ENERGY FOR SYSTEM

STEP NO	TIME (SEC.)	KINETIC ENERGY (IN-K)	POTENTIAL ENERGY (IN-K)	TOTAL PE + KE (IN--K)
1	.0000	1523.	0.	1523.
2	.1097	1182.	349.	1531.
3	.2195	463.	1083.	1546.
4	.3292	13.	1543.	1555.

```
        TOTAL KINETIC ENERGY OF SHIP =      1523. K-IN
  TOTAL POTENTIAL ENERGY OF DOLPHIN =      1543. K-IN
                            ERROR =       -1.30 PERCENT
```

```
**********************************************************
*****                                                *****
*****  MAXIMUM DEFLECTION AT ML =        .111 INCHES *****
*****                                                *****
**********************************************************
```

FACTOR OF SAFETY =   139.609

EXAMPLE 4

General

The purpose of this example is to present the computer analysis
of a bridge cell protective system. The bridge, as shown in Figure
19, is located north of St. Louis, Missouri; across the Illinois
River near the city of Pearl, Illinois.

As described previously the method of analysis consists of a
computer oriented dynamic response program, which can analyze various
fendering schemes on single dolphins, clusters of cells.

The basic theory involves matrix formulation of interactive
pilings, attached by cross members, which support energy absorbing
fenders. Soil characteristics can be designated along the length
of the embedded pilings. Isolated dolphins are similarly modeled,
and can include wood clusters with cabled wrappings, rigid pile
clusters or cells.

In general, the input requirements are the ship tonnage, speed,
direction, rigidity of supporting elements, cantilever length, en-
ergy characteristics of fenders, soil parameters and general geo-
metry of system. The output information includes velocity and
acceleration of vessel at any time interval and the corresponding
forces and deformations throughout the system.

BRIDGE DESCRIPTION

The replaced bridge consists of a 367 ft., vertical lift steel
truss, which will provide a 69' vertical clearance to the shipping

traffic. The previous bridge, which was a swing structure had a 149' clear channel. This new structure will provide a 315 ft clear channel, as shown in Figure 20.

PROTECTIVE CELL

In order to protect the new bridge piers, four steel cells, will be positioned near the bridge as shown in Figure 2. These cells consist of steel sheet piling (58 sheets/cell) with a 24'-7 3/8" diameter. The units are 61.0 ft. long and are filled with 2500 psi lean concrete, as shown in Figure 21. The cell will have a cantilever length of 36 ft. if the existing river bed is maintained and 41 ft. for the dredged river. The vessel, which will impact the cell, was assumed as follows and dictated by the USCG;

Wt. (tons)	Velocity (knots)
10,000	0.40
1,000	1.40

COMPUTER RESULTS

a) Systems Analyzed

Two basic systems were analyzed, one which consists of only the infill concrete, and the other the steel shell. The cantilever length was changed for the concrete unit in order to examine the effect. The basic model is shown in Figure 22, and shows the cantilever length of the cell and the embedment length. Although, the concrete will not be acting independent of the steel, the effect of its stiffness is generally neglected in evaluating the strength of the steel shell. It was for this reason that the region of the concrete mass was examined.

b) Case Studies

As shown in Table 7, five case solutions were conducted. Cases 1 through 3, consisted of only the 27' diameter concrete mass and cases 4 and 5 consisted of the steel shell. The variations within each type was due to vessel weight and velocity and cantilever lengths.

c) Computer Output

Using the various parameters required for each of the five cases, a computer solution was obtained. The resulting output, which consists of a description of the input parameters and the final dynamic data, is given in Table 9.

Examination of these data shows that the steel cell will deform a maximum of 3.03 inches and a maximum stress of 8.2 ksi. A summary of the data for all five cases is shown in Table 8.

193

V. RECOMMENDATIONS

The computer response of the 1" thick-28' round steel cell indicates that it will perform adequately when impacted by a ship of 10,000. T (0.4 knots) or 1000.T(1.4 knots). The maximum deformation of the cell is 3.83 inches and develops a maximum steel stress of 8.2 ksi.

TABLE 7

ANALYTICAL STUDIES

Case No.	Description	Cantilever Length (ft)	Ship Details	
1	Concrete Mass	36	$10,000^T$	0.4 knots
2	Concrete Mass	36	$1,000^T$	1.4 knots
3	Concrete Mass	41	$1,000^T$	1.4 knots
4	Steel Shell – 1" thick	36	$1,000^T$	1.4 knots
5	Steel Shell – 1" thick	36	$10,000^T$	0.4 knots

TABLE 8

SUMMARY OF RESULTS

CASE	CONDITION	DEFL (in)	FORCE (kips)	MOMENT (k-in)	SECTION (in³)	STRESS (ksi)	STRESS ULT (ksi)	STATUS
1	conc.	3.38	1115.0	522335.	2.56×10^6	.204	.400	OK
2	conc.	3.74	1234.0	578162.	2.56×10^6	.226	.400	OK
3	conc.	5.98	772.	398077.	2.56×10^6	.155	.400	OK
4	cell	3.83	1206.	564822.	6.9×10^4	8.2	36.	OK
5	cell	3.44	1090.	510322.	6.9×10^4	7.4	36.	OK
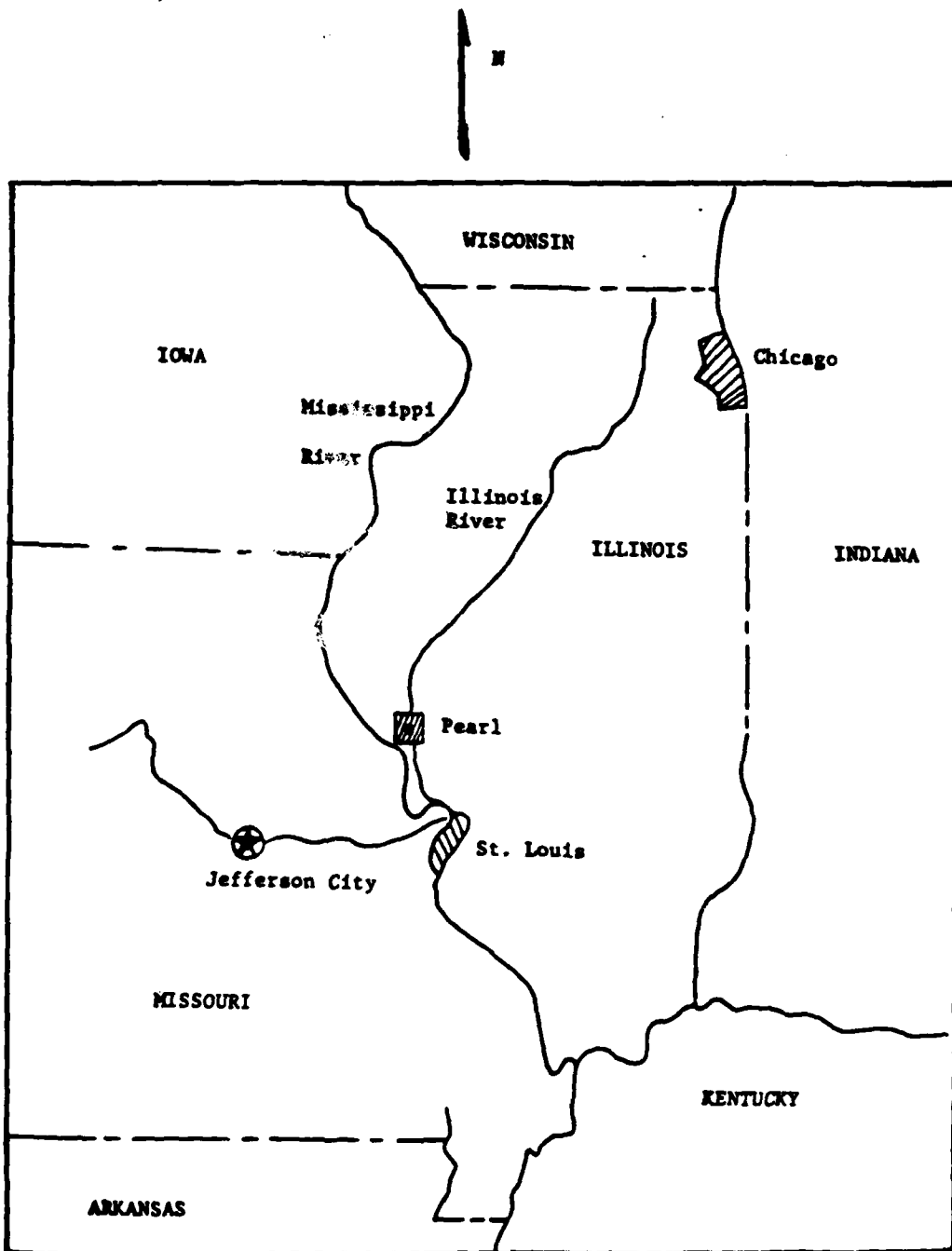
BRIDGE LOCATION

FIGURE 19

58'

58'

#2

315' Chanl.

Flow

N

#1

#3

#4

CELL PLAN

FIGURE 20

197

24'-7 3/8" Dia.

Flood

5'

Conc Fill

Nrml. Pl.

44'   61'

Exist Riv. Bd.

36'

Assum. Drgd. Bd.

41'

CELL DETAILS

FIGURE 21

198

Top

Ship (M^T, v^k)

Cantilever
Length

Dis. Below
M.L.
(inches)

M.L.
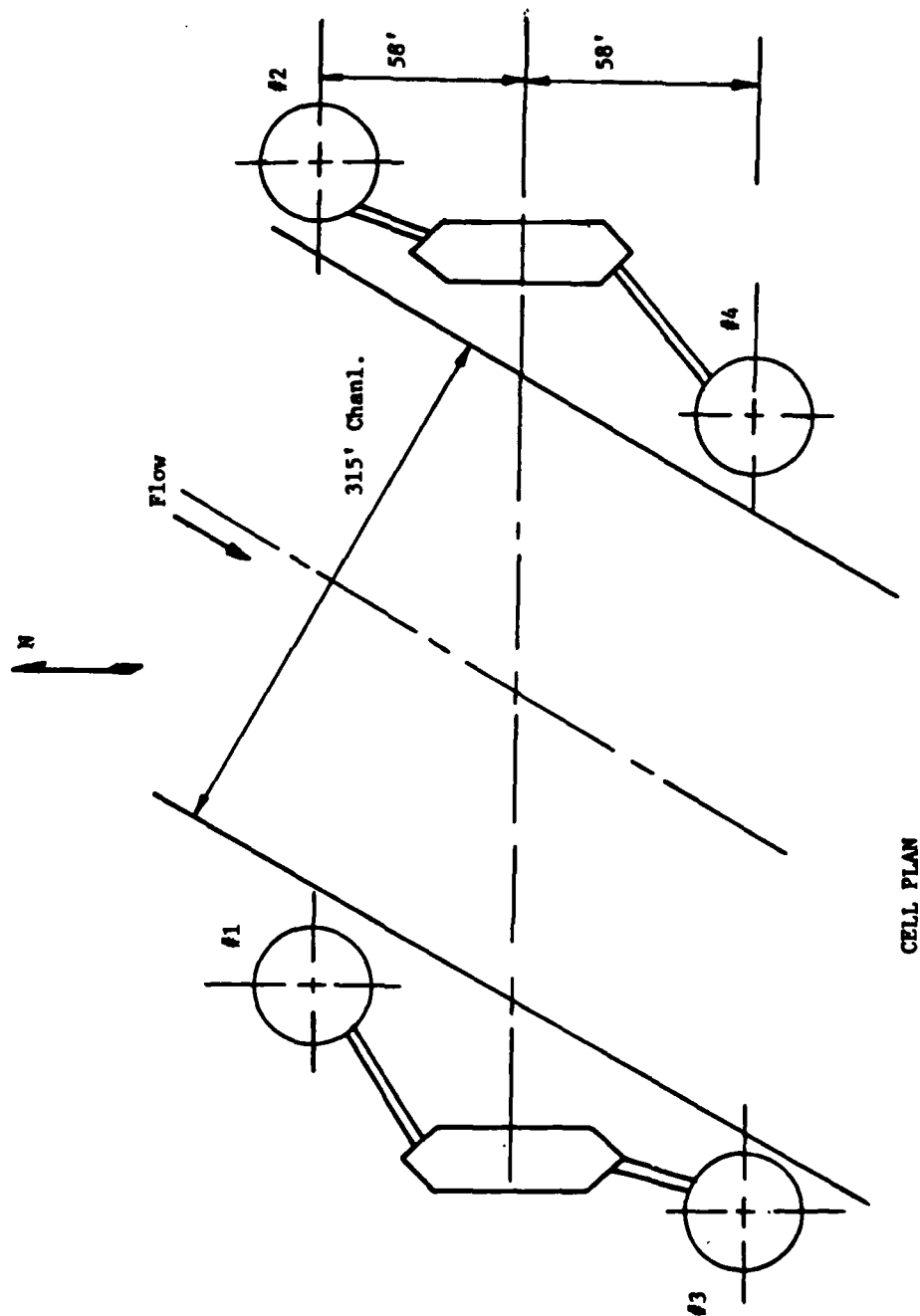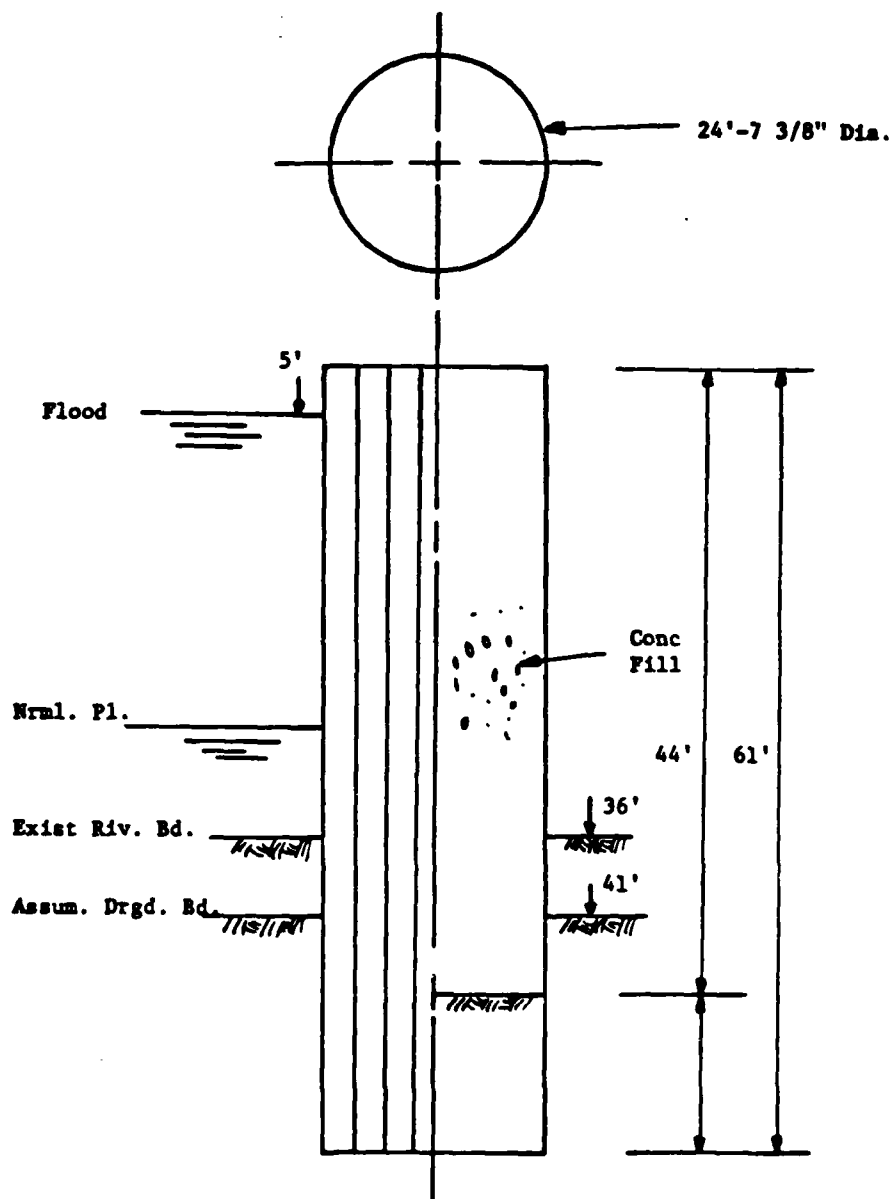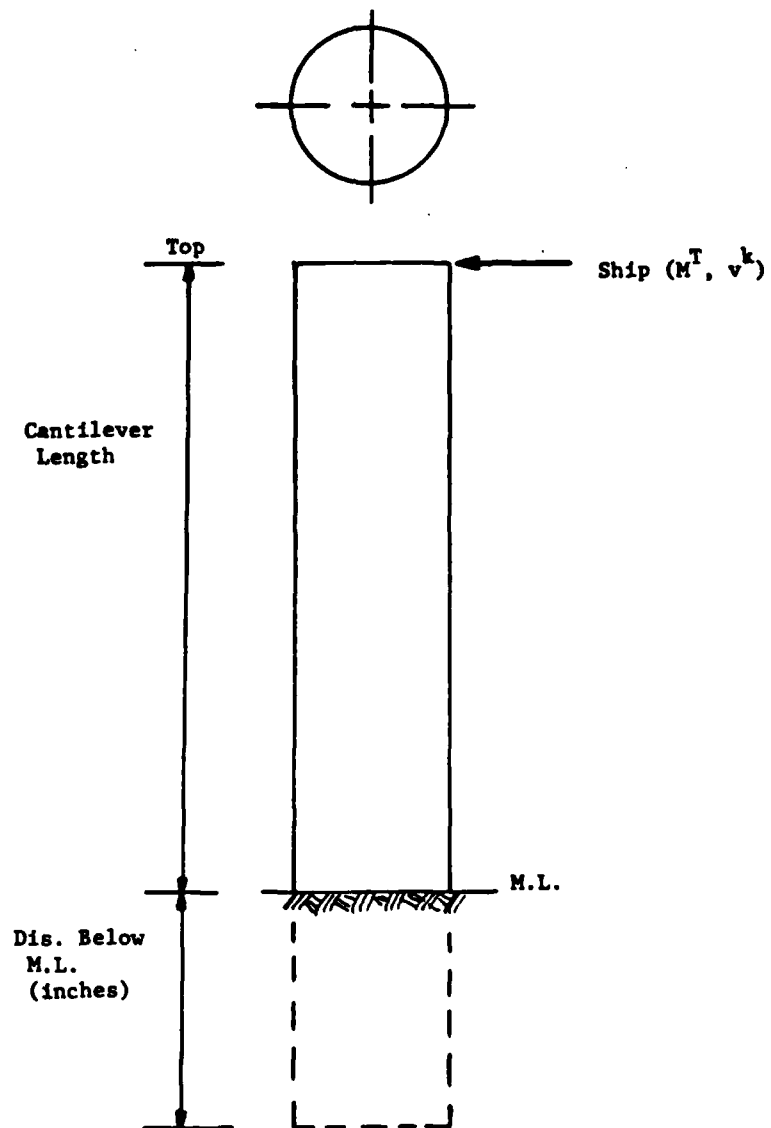
CELL MODEL

FIGURE 22

199

BASIC PROGRAM PARAMETERS

```
                WEIGHT OF SHIP =    10000.00 TONS  ( 22400.00 KIPS)
              VELOCITY OF SHIP =       24.75 KNOTS (     8.10 IPS)
        DIAMETER OF DOLPHIN =        24.75 FEET
 WALL THICKNESS OF DOLPHIN =         2.000 INCHES
 LENGTH OF DOLPHIN BELOW ML =       25.00 FEET
 LENGTH OF DOLPHIN ABOVE ML =       36.00 FEET
             MASS OF SHIP =       56.02 KIPS/IN/SEC/SEC
  MOMENT OF INERTIA OF DOLPHIN = 37263416.0 IN**4
 ANGLE OF PASSIVE FAILURE =       45.00 DEGREES
        DEPTH CORRECTION =         .00 FEET
     DISSIPATION FACTOR =        .5000 IN/IN
       ALLOWABLE STRAIN =        .00000 IN/IN
 ALLOWABLE ELASTIC DEFLECTION =    4.645 INCHES
              STEPSIZE =         .06029 SEC
```

DYNAMIC RESULTS FOR LINEAR SPRINGING

```
 MAX. DEFLECTION AT POINT OF IMPACT =       3.419 INCHES
       MAXIMUM SHIP ACCELERATION =      19.1670 IN/SEC**2
           MAXIMUM SHIP FORCE =       1119.82 KIPS
              STOPPING TIME =         .6029 SECONDS
    INITIAL SPRING CONSTANT =        .072.78 K/IN
         LINEAR LAMBDA FACTOR =        2.1626 1/SEC
```

TABLE 9

DOLPHIN/SOIL LOADS AND DEFORMATIONS AT TIME = .72616 SECONDS

DEPTH BELOW MUD.L (IN)	SOIL MODULUS (K/SQ IN)	SOIL RESISTANCE ALLOW (K/IN)	ACTUAL (K/IN)	DOLPHIN DEFL. DEFL (IN)	SLOPE (RAD)	DOLPHIN M AND V MOMENT (IN-K)	SHEAR (K)

OUTPUT OF DYNAMIC DATA AT THE POINT OF IMPACT

STEP NO	TIME (SEC)	DEFL (IN)	VELOCITY (IN/SEC)	ACCELERATION (IN/SEC/SEC)	FORCE (K)	SPRING K (K/IN)

OUTPUT OF KINETIC AND POTENTIAL ENERGY FOR SYSTEM

STEP NO	TIME (SEC.)	KINETIC ENERGY (IN-K)	POTENTIAL ENERGY (IN-K)	TOTAL PE+KE (IN-K)
1	.0000	1994.	0.	1994.
2	.0000	1856.	67.	1953.
3	.1020	1722.	181.	1903.
4	.1520	1517.	385.	1902.
5	.2052	1249.	650.	1899.
6	.7717	956.	951.	1907.
7	.4040	660.	1247.	1907.
8	.5353	393.	1515.	1908.
9	.5900	183.	1725.	1908.
10	.5900	47.	1861.	1908.
11	.6029	0.	1908.	1908.

TOTAL KINETIC ENERGY OF SHIP =   1994. K-IN
TOTAL POTENTIAL ENERGY OF DOLPHIN =   1908. K-IN
                            ERROR =   -.22 PERCENT

MAXIMUM DEFLECTION AT ML =   1.005 INCHES

FACTOR OF SAFETY =   24.999

BASIC PROGRAM PARAMETERS

        WEIGHT OF SHIP = 1000.00 TONS (2240.00 KIPS)
      VELOCITY OF SHIP = 16.0 KNOTS (26.36 IPS)
    DIAMETER OF DOLPHIN = 24.70 FEET
WALL THICKNESS OF DOLPHIN = ...000 INCHES
LENGTH OF DOLPHIN BELOW ML = 45.000 FEET
LENGTH OF DOLPHIN ABOVE ML = 45.000 FEET
          MASS OF SHIP = 5.80 KIPS/SEC-2/IN-2/IN/SEC/SEC
MOMENT OF INERTIA OF DOLPHIN = 372863.16.5
ANGLE OF PASSIVE FAILURE = 45.00 DEGREES
     DEPTH CORRECTION = 45.00 FEET
   DISSIPATION FACTOR = .5796 IN/IN
     ALLOWABLE STRAIN = .03000 IN/IN
ALLOWABLE ELASTIC DEFLECTION = 24.485 INCHES
             STEPSIZE = .02005 SEC

DYNAMIC RESULTS FOR LINEAR SPRINGING

MAX. DEFLECTION AT POINT OF IMPACT = 3.794 INCHES
     MAXIMUM SHIP ACCELERATION = 217.4720 IN/SEC**2
          MAXIMUM SHIP FORCE = 1232.77 KIPS
              STOPPING TIME = .2556 SECONDS
      INITIAL SPRING CONSTANT = 425.78 K/IN
        LINEAR LAMBDA FACTOR = 7.4933 1/SEC

DOLPHIN/SOIL LOADS AND DEFORMATIONS AT TIME = .27059 SECONDS

DEPTH BELOW M.L. (IN)	SOIL MODULUS (K/SQ IN)	SOIL RESISTANCE ALLOW (K/IN)	ACTUAL (K/IN)	DOLPHIN DEFL. DEFL (IN)	SLOPE (RAD)	DOLPHIN M AND V MOMENT (IN-K)	SHEAR (K)

OUTPUT OF DYNAMIC DATA AT THE POINT OF IMPACT

STEP NO	TIME (SEC)	DEFL (IN)	VELOCITY (IN/SEC)	ACCELERATION (IN/SEC/SEC)	FORCE (K)	SPRING K (K/IN)

OUTPUT OF KINETIC AND POTENTIAL ENERGY FOR SYSTEM

STEP NO	TIME (SEC.)	KINETIC ENERGY (IN-K)	POTENTIAL ENERGY (IN-K)	TOTAL PE + KE (IN-K)
1	.0000	2336.	0.	2336.
2	.0210	2275.	57.	2333.
3	.0419	2106.	225.	2332.
4	.0629	2026.	2301.	2332.
5	.0848	1152.	1167.	2332.
6	.1056	0810.	1524.	2332.
7	.1267	0404.	1929.	2332.
8	.1477	0126.	2270.	2332.
9	.1677	0.	2336.	2332.
10	.2096			

TOTAL TOTAL KINETIC ENERGY OF SHIP = 2732. K-IN
TOTAL POTENTIAL ENERGY OF DOLPHIN = 2738. K-IN
ERROR = -.22 PERCENT

MAXIMUM DEFLECTION AT ML = 1.212 INCHES

FACTOR OF SAFETY = 24.111

BASIC PROGRAM PARAMETERS

```
              WEIGHT OF SHIP =    1000.00 TONS  (  2240.00 KIPS)
            VELOCITY OF SHIP =       1.43 KNOTS (    26.36 IPS)
         DIAMETER OF DOLPHIN =      24.00 FEET
    WALL THICKNESS OF DOLPHIN =     20.000 INCHES
       LENGTH OF DOLPHIN BELOW ML =   20.00 FEET
       LENGTH OF DOLPHIN ABOVE ML =   41.00 FEET

  MOMENT OF INERTIA OF DOLPHIN = 3768.3416  KIPS/IN/SEC/SEC
     ANGLE OF PASSIVE FAILURE =      45.00 DEGREES
           DEPTH CORRECTION =       .50.0 FEET
         DISSIPATION FACTOR =       .0300C IN/IN
        ALLOWABLE ELASTIC STRAIN =    .03595 INCHES
              STEPSIZE =       .03545 SEC
```

DYNAMIC RESULTS FOR LINEAR SPRINGING

```
  MAX. DEFLECTION AT POINT OF IMPACT =     6.069 INCHES
        MAXIMUM SHIP ACCELERATION =   132.9172 IN/SEC**2
          MAXIMUM SHIP FORCE =     371.16 KIPS
        SHIP STOPPING TIME =      .3551 SECONDS
      INITIAL SPRING CONSTANT =      167.48 K/IN
        LINEAR LAMBDA FACTOR =       4.5674 1/SEC
```

DOLPHIN/SOIL LOADS AND DEFORMATIONS AT TIME = .34662 SECONDS

DEPTH BELOW M.L. (IN)	SOIL MODULUS (K/SQ IN)	SOIL RESISTANCE ALLOW. (K/IN)	SOIL RESISTANCE ACTUAL (K/IN)	DOLPHIN DEFL. DEFL (IN)	DOLPHIN DEFL. SLOPE (RAD)	DOLPHIN M AND V MOMENT (IN-K)	DOLPHIN M AND V SHEAR (K)

OUTPUT OF DYNAMIC DATA AT THE POINT OF IMPACT

STEP NO	TIME (SEC)	DEFL (IN)	VELOCITY (IN/SEC)	ACCELERATION (IN/SEC/SEC)	FORCE (K)	SPRING K (K/IN)

OUTPUT OF KINETIC AND POTENTIAL ENERGY FOR SYSTEM

STEP NO	TIME (SEC.)	KINETIC ENERGY (IN-K)	POTENTIAL ENERGY (IN-K)	TOTAL PE + KE (IN--K)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				

TOTAL KINETIC ENERGY OF SHIP = 2732. K-IN
TOTAL POTENTIAL ENERGY OF DOLPHIN = 2338. K-IN
ERROR = -.27 PERCENT

MAXIMUM DEFLECTION AT ML = 1.509 INCHES

FACTOR OF SAFETY = 16.744

BASIC PROGRAM PARAMETERS

```
        WEIGHT OF SHIP   =    1000.00 TONS   (   2240.00 KIPS)
        VELOCITY OF SHIP =      14.00 KNOTS  (     28.36 IPS)
  WALL DIAMETER OF DOLPHIN =   24.000 FEET
 LENGTH OF DOLPHIN BELOW ML =    1.000 INCHES
 LENGTH OF DOLPHIN ABOVE ML =   36.00 FEET
         MASS OF SHIP     =
 MOMENT OF INERTIA OF DOLPHIN = 122257330.4 KIPS/IN**2 IN/SEC/SEC
 ANGLE OF PASSIVE FAILURE  =   45.00 DEGREES
       DEPTH CORRECTION    =         FEET
    DISSIPATION FACTOR     =   .5000
    ALLOWABLE STRAIN       =   .07000 IN/IN
 ALLOWABLE ELASTIC DEFLECTION = .07485 INCHES
            STEPSIZE       =   .02145 SEC
```

DYNAMIC RESULTS FOR LINEAR SPRINGING

```
 MAX. DEFLECTION AT POINT OF IMPACT =     3.871 INCHES
   MAXIMUM SHIP ACCELERATION  =   207.0800 IN/SEC**2
        MAXIMUM SHIP FORCE    =   13265.03 KIPS
        STOPPING TIME         =    .2145 SECONDS
   INITIAL SPRING CONSTANT    =    411.23 K/IN
      LINEAR LAMBDA FACTOR    =   7.2240 1/SEC
```

DOLPHIN/SOIL LOADS AND DEFORMATIONS AT TIME = .23590 SECONDS

DEPTH BELOW M.L. (IN)	SOIL MODULUS (K/SQ IN)	SOIL RESISTANCE ALLOW. (K/IN)	RESISTANCE ACTUAL (K/IN)	DOLPHIN DEFL. DEFL (IN)	DOLPHIN DEFL. SLOPE (RAD)	DOLPHIN M MOMENT (IN-K)	DOLPHIN M AND V SHEAR (K)

OUTPUT OF DYNAMIC DATA AT THE POINT OF IMPACT

STEP NO	TIME (SEC)	DEFL (IN.)	VELOCITY (IN/SEC)	ACCELERATION (IN/SEC/SEC)	FORCE (K)	SPRING K (K/IN)

214

OUTPUT OF KINETIC AND POTENTIAL ENERGY FOR SYSTEM

STEP NO	TIME (SEC.)	KINETIC ENERGY (IN-K)	POTENTIAL ENERGY (IN-K)	TOTAL PE+KE (IN-K)
1	.0000	2732.	0.	2732.
2	.0422	2375.	357.	2733.
3	.0442	2310.	223.	2735.
4	.0604	2052.	451.	2745.
5	.0707	1160.	1606.	2767.
6	.1035	831.	1924.	2766.
7	.1501	224.	1654.	2877.
8	.1709	56.	2119.	2835.
9	.1939	0.	2278.	2337.
10	.2145	0.	2376.	2336.
11				

TOTAL KINETIC ENERGY OF SHIP = 2732. K-IN
TOTAL POTENTIAL ENERGY OF DOLPHIN = 2738. K-IN
ERROR = -.22 PERCENT

MAXIMUM DEFLECTION AT AL = 1.196 INCHES

FACTOR OF SAFETY = 24.111

BASIC PROGRAM PARAMETERS

```
                  WEIGHT OF SHIP  =  10000.00 TONS  (   22400.00 KIPS)
                VELOCITY OF SHIP  =     24.0 KNOTS  (      8.10 IPS)
          DIAMETER OF DOLPHIN  =     24.00 FEET
    WALL THICKNESS OF DOLPHIN  =      1.000 INCHES
    LENGTH OF DOLPHIN BELOW ML  =     25.00 FEET
    LENGTH OF DOLPHIN ABOVE ML  =     36.00 FEET
             MASS OF SHIP  =     58.02 KIPS/IN/SEC/SEC
  MOMENT OF INERTIA OF DOLPHIN  =  15225.7    IN**4 IN**2
    ANGLE OF PASSIVE FAILURE  =     45.00 DEGREES
          DEPTH CORRECTION  =      5.00 FEET
         DISSIPATION FACTOR  =      .500
      ALLOWABLE STRAIN  =      .07000 IN/IN
   ALLOWABLE ELASTIC DEFLECTION  =      .06735 INCHES
               STEPSIZE  =      .06752 SEC
```

DYNAMIC RESULTS FOR LINEAR SPRINGING

```
  MAX. DEFLECTION AT POINT OF IMPACT  =      3.498 INCHES
       MAXIMUM SHIP ACCELERATION  =     18.7650 IN/SEC**2
          MAXIMUM SHIP FORCE  =   1089.75 KIPS
          STOPPING TIME  =      .6752 SECONDS
        INITIAL SPRING CONSTANT  =    311.3 K/IN
          LINEAR LAMBDA FACTOR  =      2.3162 1/SEC
```

216

DOLPHIN/SOIL LOADS AND DEFORMATIONS AT TIME =   .74568 SECONDS

DEPTH BELOW M.L. (IN) TOP	SOIL MODULUS (K/SQ IN)	SOIL RESISTANCE ALLOW (K/IN)	ACTUAL (K/IN)	DOLPHIN DEFL. DEFL (IN)	SLOPE (RAD)	DOLPHIN M AND V MOMENT (IN-K)	SHEAR (K)

OUTPUT OF KINETIC AND POTENTIAL ENERGY FOR SYSTEM

STEP NO	TIME (SEC.)	KINETIC ENERGY (IN-K)	POTENTIAL ENERGY (IN-K)	TOTAL PE + KE (IN-K)
1	.0000	1904.	0.	1904.
2	.0678	1856.	47.	1904.
3	.1356	1722.	172.	1905.
4	.2034	1512.	703.	1905.
5	.2712			
6	.3391	1655.	950.	1905.
7	.4069		1447.	1907.
8	.4747	904.	1513.	1907.
9	.5425	793.	1725.	1908.
10	.6103	347.	1361.	1908.
11	.6782	0.	1900.	1905.

TOTAL TOTAL KINETIC ENERGY OF SHIP = 1904. K-IN
TOTAL POTENTIAL ENERGY OF DOLPHIN = 1905. K-IN
ERROR = -.22 PERCENT

MAXIMUM DEFLECTION AT ML = 1.033 INCHES

FACTOR OF SAFETY = 29.033

OUTPUT OF DYNAMIC DATA AT THE POINT OF IMPACT

STEP NO	TIME (SEC)	DEFL (IN)	VELOCITY (IN/SEC)	ACCELERATION (IN/SEC/SEC)	FORCE (K)	SPRING K (K/IN)

CHAPTER VII

CONCLUSIONS

The results of this study have led to several major conclusions:

1. The majority of fendering systems used in this country con-
   sist of pile or rubber fenders or a combination of the two.
   These systems were generally designed by experience rather
   than by detailed energy considerations resulting in both
   over and under design.

2. The variety of fendering systems available allows design
   control over a wide range of stiffness and energy criterion.
   Combining several systems in one installation may yield a
   more appropriate design than a homogeneous system.

3. Wood is the most commonly used fendering material due to
   its high fiber strength and hardness, its resilence, its
   relative abundance and low cost. Whenever wood is used in
   the marine environment, it must be protected by some treat-
   ment preventing borer, termite, and ant attack as well as
   reducing the abrasive effects of sand, silt, and ice.

4. Steel sections used in fendering systems must be heavily
   protected against corrosion and abrasion. Shotcrete and
   gunite have been used in the past,but the development of
   plastic, acrylic, or resin coatings may be preferrable.
   Steel sections are used where long lengths, low displace-
   ment, and high strength are required.

5. Concrete structures tend to be massive and too stiff for
   many vessels. Rubber or timber rubbing strips are necessary

on exposed concrete faces. The concrete mix should have a cement content between 6-1/2 sacks/cu. yd. and 7-1/2 sacks/cu. yd. The aggregates should be graded for maximum density and non-reactive. The water content should be the lowest possible to provide a workable, plastic mix, but not to exceed six gallons/sack of cement. Type V or Type II cements are preferrable and three percent to six percent entrained air is recommended to increase abrasion resistance and workability. Adequate vibration is necessary to ensure concrete strength. Minimum depth of covering over reinforcement should be three inches.

6. Complete detailed design of a fender system and its support structure requires the use of a rigid mass and spring model. This process would be extremely difficult without the use of computers. This system is currently being developed.

7. In lieu of a computer package, hand calculations may be based on the following design parameters: approach angle and velocity, ship displacement, draft and beam, general configuration of the support system (open, partially open, closed), an assumed stiffness between the fender and support structure, impact point, and the stiffness and energy absorption characteristics of the fender. These calculations do not account for the distribution among piles of horizontal loads on a piling system. Nor do they consider the effects of soil deformation and the resulting shift in the fixed point of the pile system. They represent an improvement over past design methods and are generally adequate.

8. The factor of safety concept should not be applied to fender design as some arbitrary multiplicative constant. The system should be designed for a range of conditions with selection based on the most serious conditions. The non-linear nature of most of the stiffness curves will generally increase the ultimate energy of the system even further. Conditions which exceed the design parameters may result in failure and sh be considered accidental occurrences, especially impact velocity.

9. Future research should deal with new fendering systems, corrosion protection of steel and concrete, development of computer simulation, and design velocities.

10. The above mentioned future research will also include a study of the rotational effect of the vessel after vessel impact. This would also include the shock absorbing effect of the hull movement.

CHAPTER VIII

RECOMMENDATIONS FOR FUTURE RESEARCH

It is obvious from the completed study that present-day bridge protection systems and devices are inadequate. In other words, they are either under or over-designed. This is attributed to the fact that tankers, containerships, and barge tows have increased in substantial size without a proportional change in design criteria or innovative ideas in the bridge protection area.

Future research should center on the design, analysis, and laboratory modeling of new and innovative ideas in fendering, protective cells and shear fences. This type of research should be incorporated into a Phase II study.

With today's inadequate bridge protective systems and devices it would be appropriate to select a specific bridge which has received considerable publicity because of its history of collisions, damages, and delays to navigation and conduct a model test in a laboratory. A typical example would be the Southern Pacific Transportation Company bridge across the Atchafalaya River at Berwick Bay, Morgan City, Louisiana. If an innovative bridge protective system or device could be developed through a model study for such a troublesome bridge as Berwick Bay, then the results of this study can be adapted to similar projects which are less hazardous.

223

APPENDIX I

GENERAL

The following pages contain tables and figures representing the stiffness and energy characteristics of particular fenders at given deflection levels. The energy tables are read by finding the fender name or size designation in the left hand column. The deflection levels are shown across the top of the tables as two digit numbers representing the percent of the maximum deflection (Δ_{max}). At the intersection of the row and column is the energy value. The units of the energy are found in the right hand margin. *The maximum deflection* (Δ_{max}) is expressed in inches unless otherwise indicated. The curve coefficient tables are read in a similar manner. These tables represent the coefficient values of a fitting function of some form which is given with each table. The deflection limits, in inches, for which the function applies is found under "upper" or "lower boundary" as appropriate. If more than one function is used for fitting, they are indicated. Finally, stiffness curves are presented for all fenders and are used to verify calculations or computed reaction forces or stiffnesses as appropriate.

APPENDIX I-A

BAKKER RUBBERFABRIEK B.V.

Table I-A-1: BAKKER ENERGY TABLE

Goliath	10	20	30	40	50	60	70	80	90	100	Δ_{max}	
800x 400					174	261	434	650	865	1216	15.7	E = K-in.
1000x 500					350	521	780	1130	1433	2000	20.5	
1200x 600				350	650	870	1303	1738	2170	2610	25.6	
1400x 800				300	475	695	950	1390	2000	3475	44.1	
1500x 800				300	475	695	1000	1564	2260	3475	43.3	
1600x 800				350	520	782	1433	2215	3300	4344	44.5	
1750x1000				1216	1650	2260	3130	3910	5213	6342	41.3	
1850x1000				1480	1910	2780	3475	4604	5950	8690	41.7	
2050x1050				1650	2085	2867	3736	4865	6973	8690	39.0	
Wing Type												
170x 100				4.0	4.8	6.6	9.3	13	26	50	2.26	E = K-in/
228x 139				3.1	5.0	6.1	8.5	13	26	66	4.04	ft. of length
Rubber Buffer				7.9	12.	20	29	37	50	66	5.22	
Cyl-axial												
21x10.5					213	230	390	565	652	825	13.8	E - K-in.
18x 9					209	221	326	434	539	652	13.8	
15x 7.5					110	170	217	278	374	440	12.2	
12x 6					55	104	110	190	217	228	10.2	
Shear												
200x 150					11	16	22	30	39	43	8.26	K-in kips
500x 250					22	35	48	61	74	96	8.86	Δ-horizon-
300x 150					30	42	55	67	87	109	8.66	tal dis-
400x 150					43	56	78	96	120	152	7.48	placement,
550x 200					56	78	109	140	161	220	7.28	inches
D-Fender												
4x 3.75					3.3	6.5	10	26	53	87	3.0	K-in.
8x 6					6.6	12	26	53	106	152	3.94	kips/foot
10x 8					13	27	37	65	119	205	5.41	
12x10					16	40	60	115	180	265	6.10	

226

Table I-A-2: BAKKER CURVE COEFFICIENT

A Goliath $K = a + b\Delta$ or
$$= a' + b'\Delta + c'\Delta^2 \qquad K = \text{Kips per inch}$$

	a	b	boundary lower	boundary upper	a'	b'	c'	boundary lower	boundary upper
800x 400	6.20	+.10	8.0	10.0	24.54	-3.30	.156	10.0	16.75
1000x 500	2.932	+.071	8.0	14.0	36.58	-4.20	.152	14.0	21.20
1200x 600	7.0	0	8.0	17.0	34.89	-3.27	.096	17.0	25.1
1400x 800	---	---	---	---	2.248	- .074	.003	8.0	39.4
1500x 800	---	---	---	---	3.188	- .084	.003	8.0	39.4
1600x 800	3.50	0	8.0	18.0	6.107	- .270	.007	18.0	47.2
1750x1000	7.35	0	8.0	29.0	24.08	-1.17	.020	29.0	39.4
1850x1000	8.40	0	8.0	29.0	27.17	-1.29	.022	29.00	39.4
2050x1050	10.50	0	8.0	29.0	41.08	-2.13	.037	29.0	39.4

B Wing Type $K = a + b\Delta$ or
$$= a' + b'\Delta + c'\Delta^2 \qquad K = \text{Kips per inch per foot}$$

	a	b	boundary lower	boundary upper	a'	b'	c'	boundary lower	boundary upper
170x 110	---	---	---	---	11.73	-19.57	10.72	.78	2.00
228x 139	1.051	+.349	.75	3.15	69.41	-40.62	6.12	3.15	4.2

C Rubber Buffer $K = a + b\Delta$ or
$$= a' + b'\Delta + c'\Delta \qquad K = \text{Kips per inch per foot}$$

a	b	boundary lower	boundary upper	a'	b'	c'	boundary lower	boundary upper
4.0	0	.75	3.15	5.25	- .820	.134	3.15	5.50

D Bakker Cylinder Axially Loaded $K = \text{Constant}$
$$K = \text{Kips per inch}$$

	k	lower	upper
21x10.5	8.6	2.0	11.8
18x 9	7.3	2.0	11.8
15x 7.5	6.0	2.0	11.8
12x 6	5.0	2.0	11.8

S   Shear Fender $K = a + b\Delta$

K = Kips per inch

	a	b	boundary lower	upper
200x150	1.302	-.011	2.0	10.0
500x250	2.214	-.007	2.0	10.0
300x150	3.0	0	2.0	10.0
400x150	5.184	-.017	2.0	8.0
550x200	7.426	-.038	2.0	6.0

F   D-Fenders $K = a + b\Delta$ or
$= a' + b'\Delta + c'\Delta^2$

K = Kips per inch per foot

	a	b	boundary lower	upper	a'	b'	c'	boundary lower	upper
4x3.75	---	---	---	---	34.72	-49.55	18.60	1.0	2.50
8x6	---	---	---	---	11.85	-13.31	5.39	1.0	4:0
10x8	5.2	0	1.0	2.0	16.20	-10.43	2.47	2.0	5.0
12x10	6.8	0	1.0	2.5	28.21	-14.92	2.54	2.5	6.0

Bakker Goliath Fenders
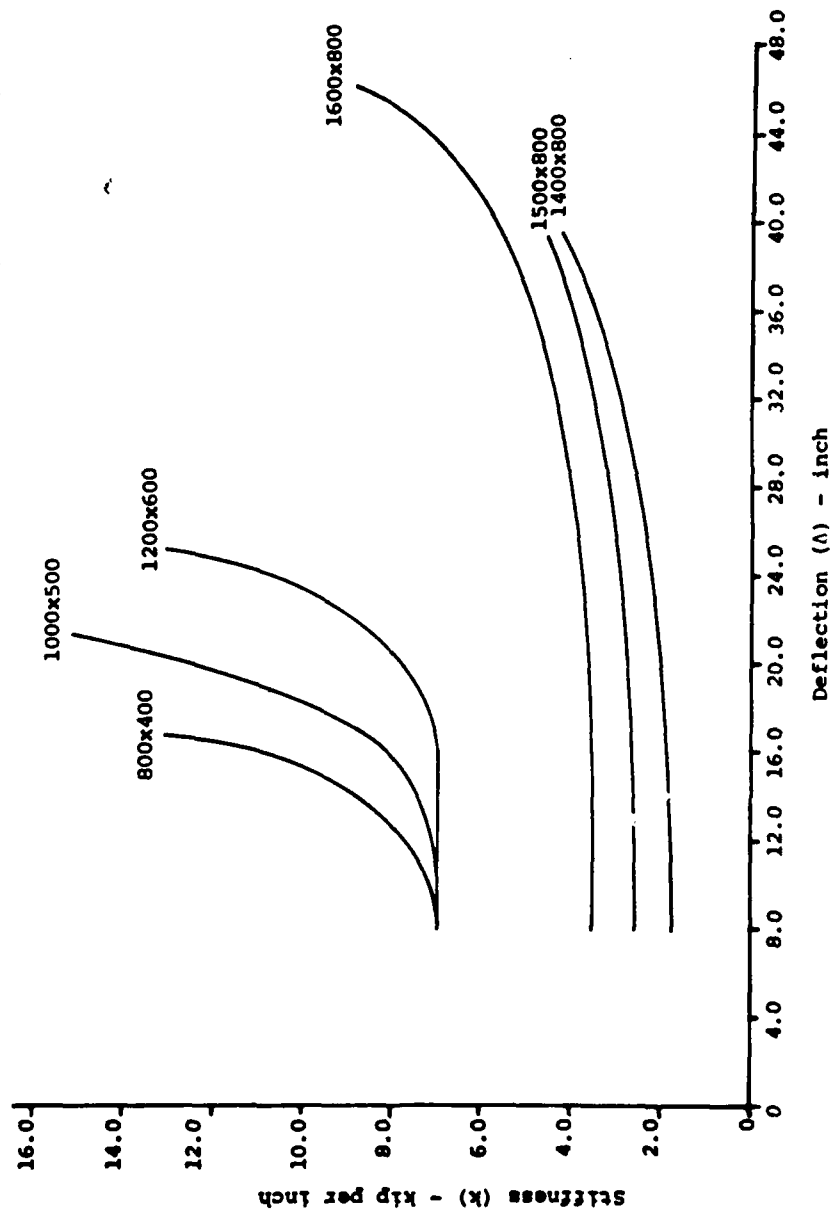
FIG. I-A-1: Stiffness vs. Deflection for Bakker Golinth Fenders up to 1600 x 800

Bakker Goliath Fenders

2050x1050x2500

1850x1000x2400

1750x1000x2000

Stiffness (k) – kips per inch

14.0
12.0
10.0
8.0
6.0
4.0
2.0
0

0   4.0   8.0   12.0   16.0   20.0   24.0   28.0   32.0   36.0   40.0

Deflection (Δ) – inch
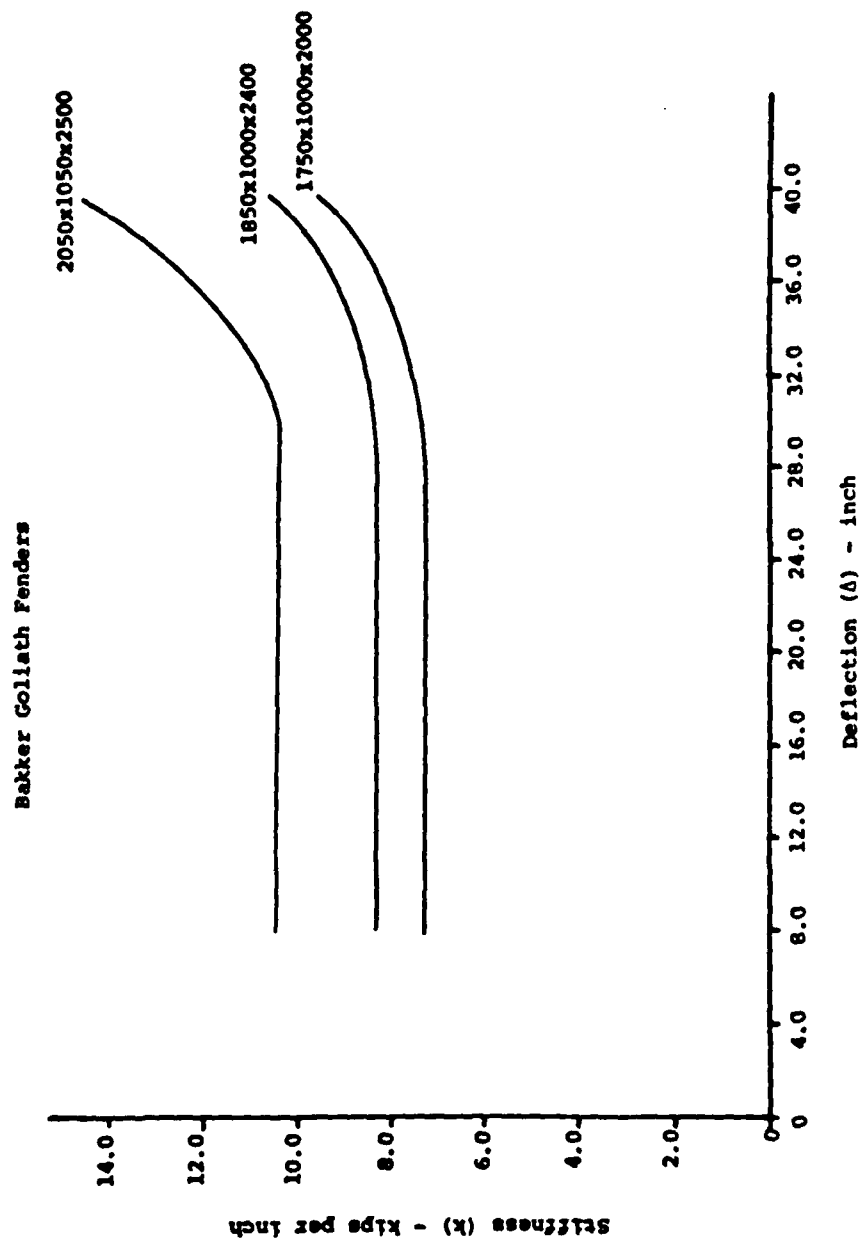
FIG. I-A-2: Stiffness vs. Deflection for Bakker Goliath up to 2050 x 1050 x 2500

Bakker Wing-type Fender
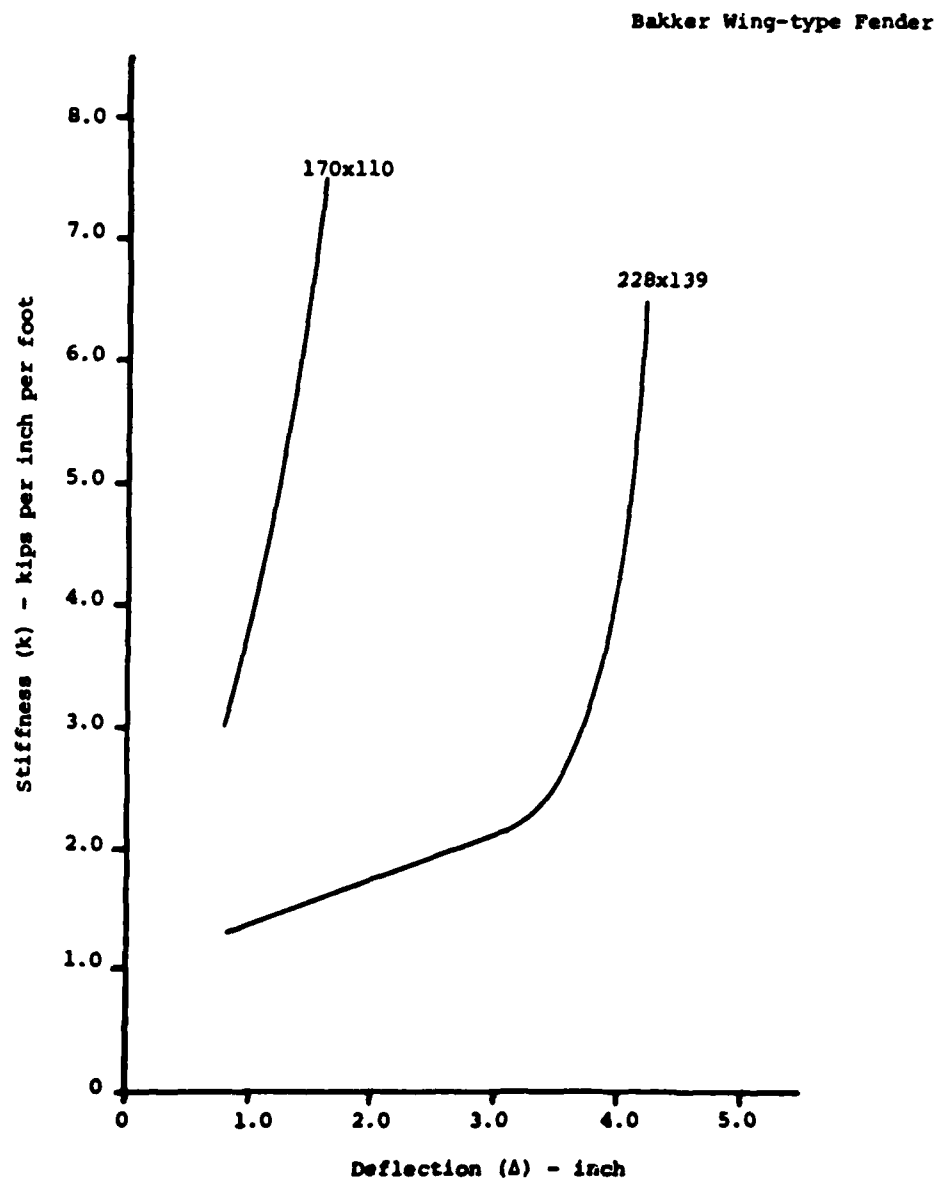
FIG. I-A-3: Stiffness vs. Deflection for Bakker Wing-type Fender

Bakker Rubber Buffer Fender
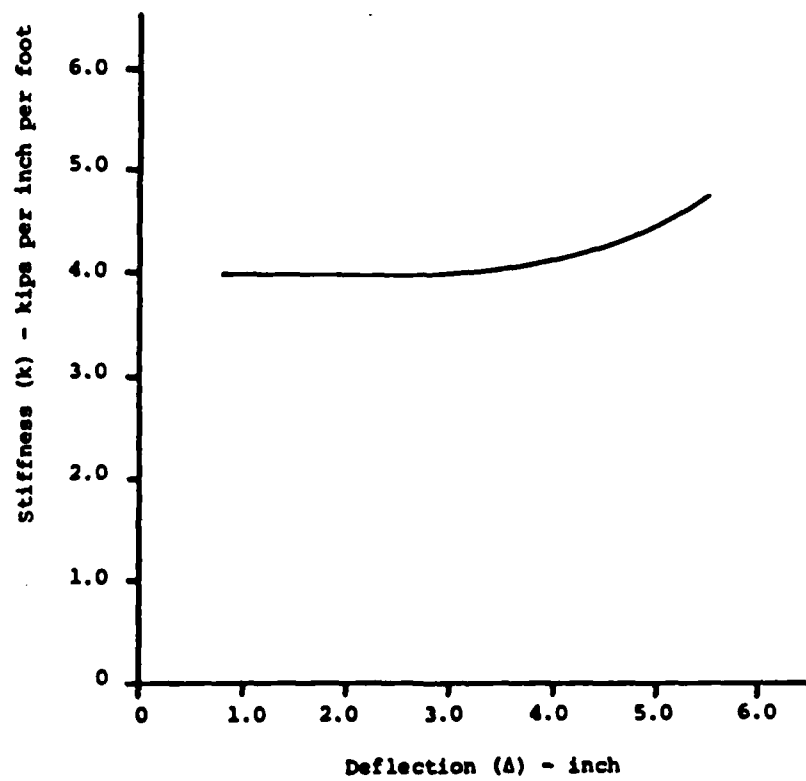
FIG. I-A-4: Stiffness vs. Deflection for Bakker Rubber Buffer Fender

Bakker Cylindrical Fender
Axial-Loading
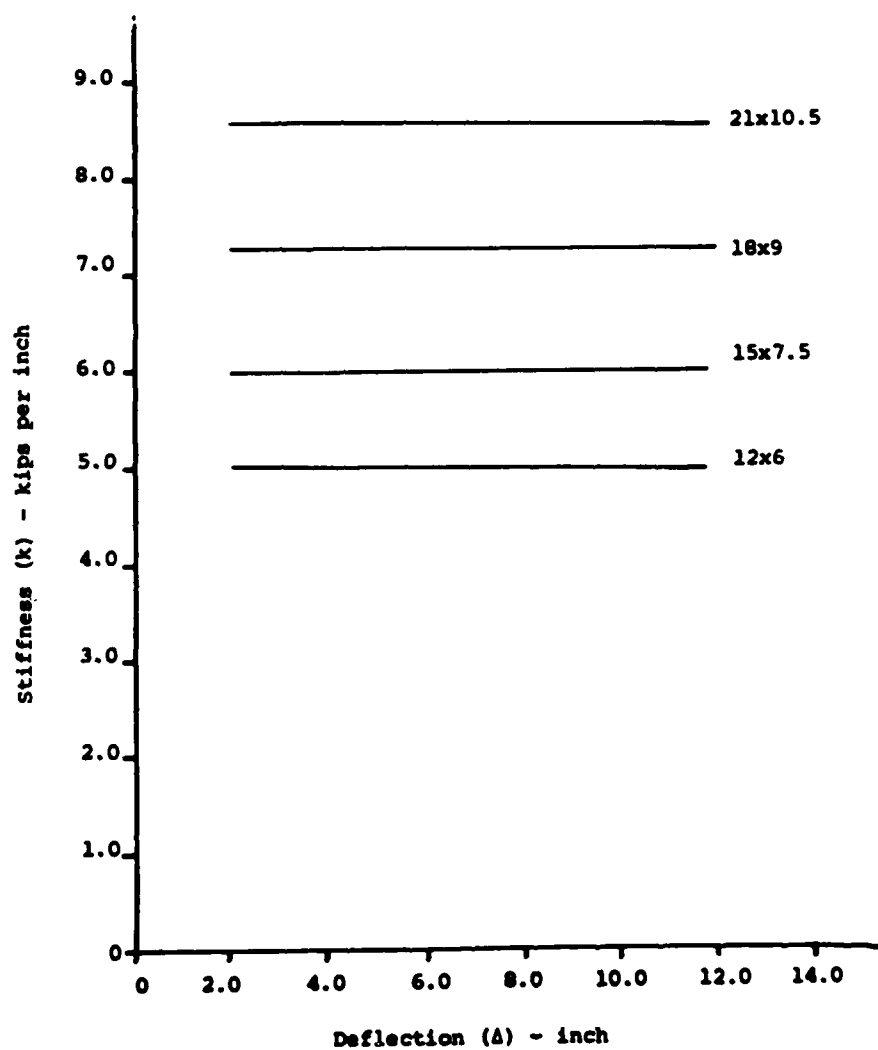
FIG. I-A-5: Stiffness vs. Deflection for Bakker Cylindrical Fender
Axially Loaded

233

Bakker Shear Fender
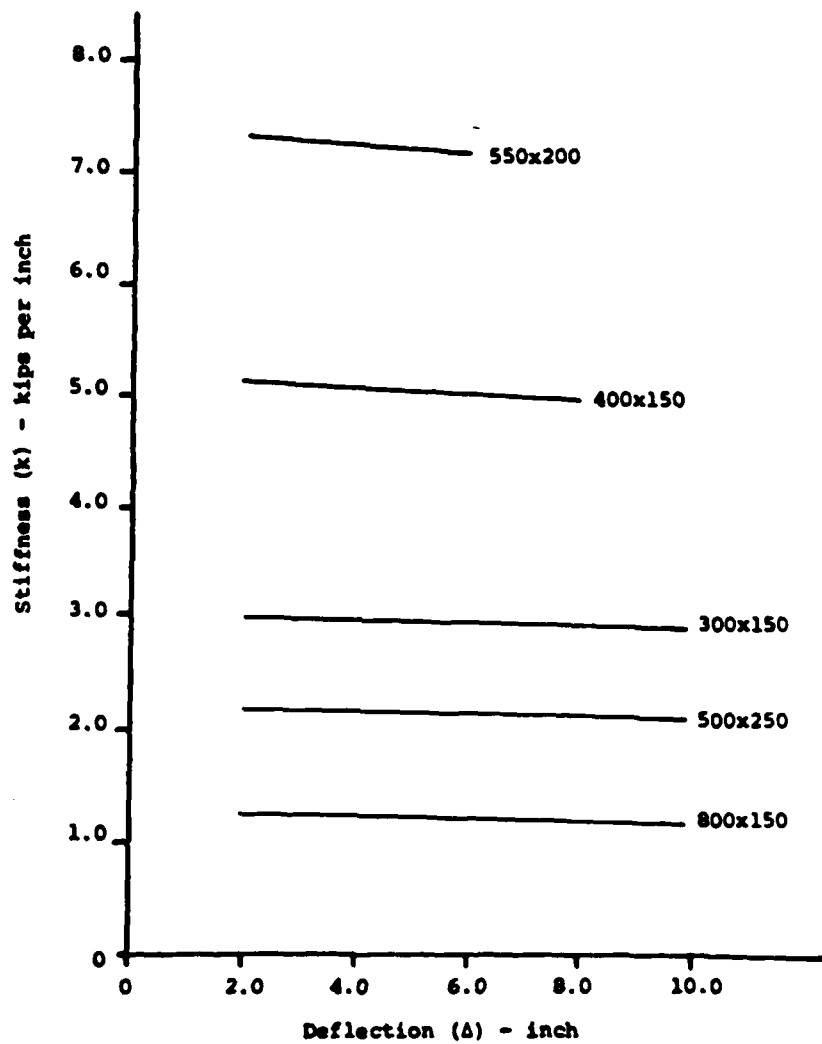
FIG. I-A-6: Stiffness vs. Deflection for Bakker Shear Fender

234
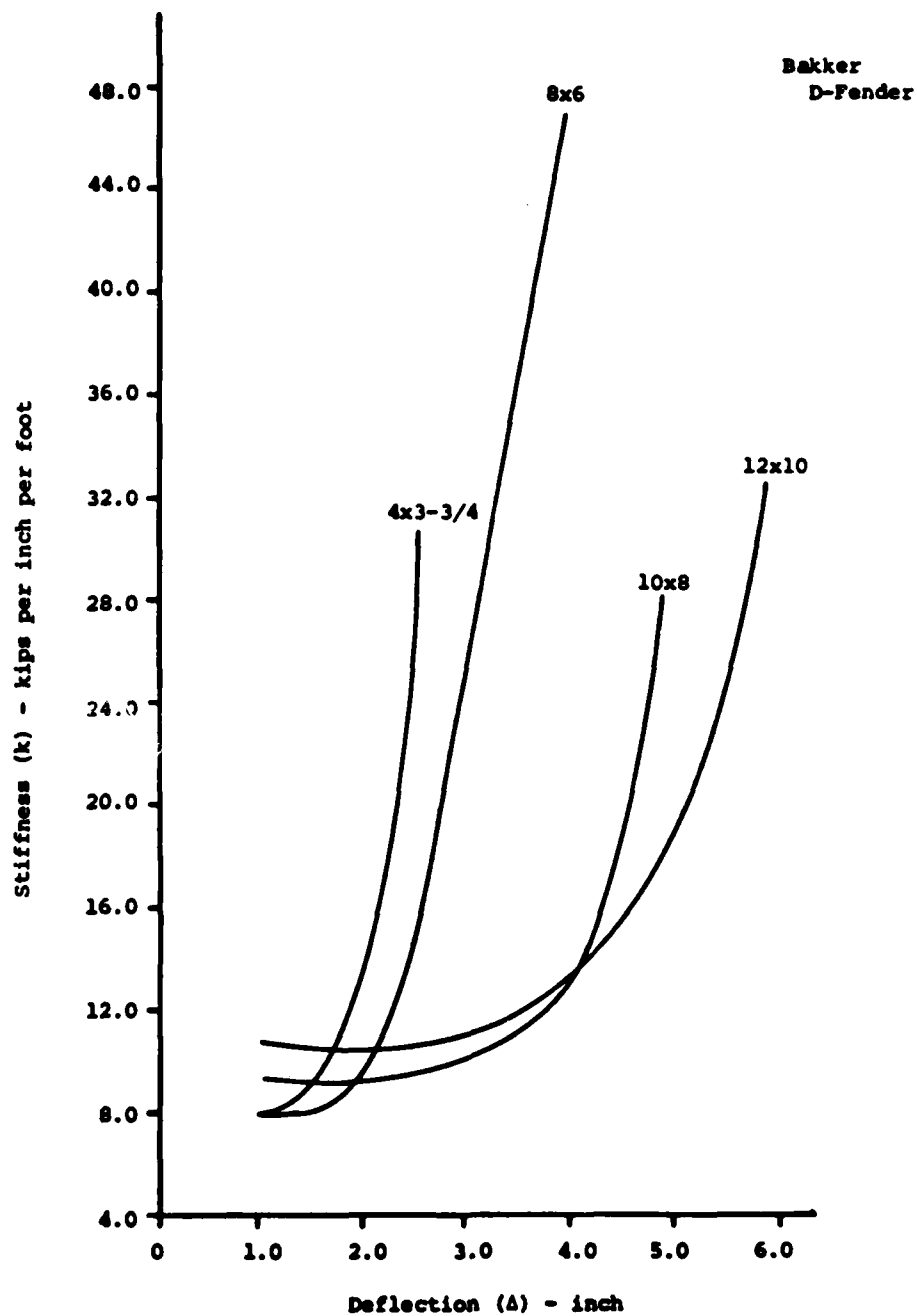
FIG. I-A-7: Stiffness vs. Deflection for Bakker D Fender

235

APPENDIX I-B

DUNLOP GRG DIVISION

Table I-B-1: DUNLOP ENERGY TABLE

	50	55	60	Δ_{max}
39" Dia.	54	78	113	E = Kip-in/per
60"	117	182	325	meter effec-
72"	165	243	375	tive length
90"	278	400	591	
108"	382	570	817	
126"	540	773	1130	
174"	1086	1615	2354	

Table I-B-2: DUNLOP CURVE COEFFICIENTS

Dunlop Pneumatics: $K = a + b\Delta + c\Delta^2$

	a	b	c	K = Kips per in. per meter effective length	
				lower	upper
39	.176	-.025	.0023		
60	.0613	-.0092	.0009		
72	-1.725	+.286	-.0052		
90	.1149	-.0084	.0004		
108	.1807	-.0132	.0004		
126	-2.22	.2133	-.0023		
174	.0835	-.0038	.0001		

238

Dunlop Pneumatic Fenders

39" Dia. 60" Dia. 72" Dia. 90" Dia. 108" Dia. 126" Dia. 174" Dia.

K-stiffness   kip per in. per meter effective length
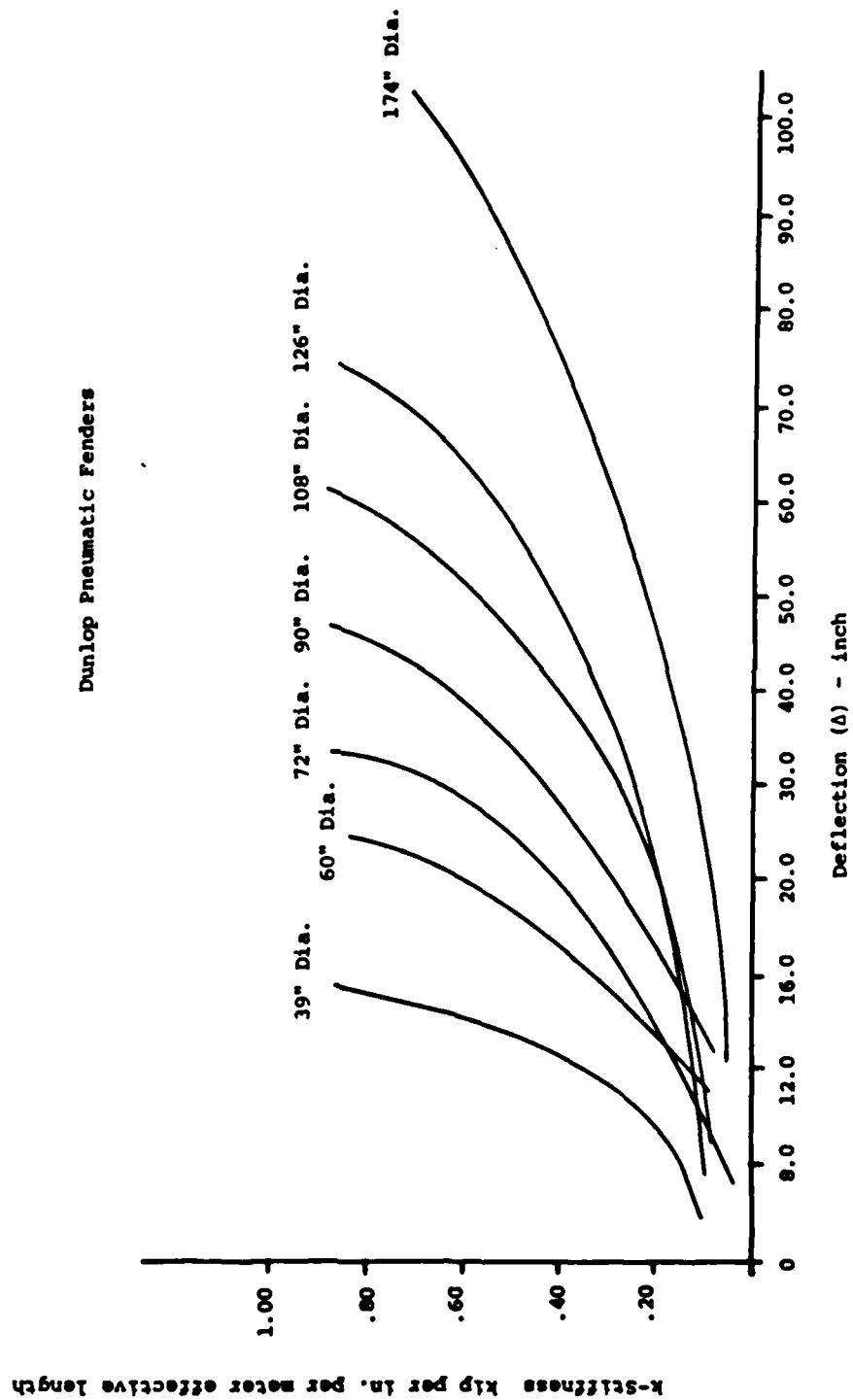
Deflection (Δ) - inch

FIG.1-B: Stiffness vs. Deflection for Dunlop Pneumatic Fenders

239

APPENDIX I-C

GENERAL TIRE AND RUBBER COMPANY

Table I-C-1: GENERAL TIRE & RUBBER - RAYKIN
ENERGY TABLE

Kip-inch

	10	20	30	40	50	60	70	80	90	100	Δ_{max}
Size C											
20 ton	16	40	64	90	118	148	180	218	256	300	11.2
25	18	44	72	104	140	178	220	270	320	370	11.2
30	20	50	84	122	162	210	260	322	380	450	11.2
35	22	60	98	140	190	144	300	376	450	530	11.2
40	30	70	112	162	216	276	340	420	500	590	11.2
45	32	76	126	178	240	302	376	468	556	650	11.2
50	35	82	136	196	260	336	420	526	624	740	11.2
60	50	112	180	250	326	410	496	610	724	850	11.2
Size D											
20 ton		16	42	80	134	172	228	290	360	436	15.0
25		24	56	100	156	218	290	374	466	570	15.0
30		30	70	120	190	274	366	472	588	710	15.0
35		40	82	140	216	312	420	542	674	820	15.0
40		50	100	166	250	354	476	610	776	960	15.0
45		56	110	180	274	396	536	690	876	1064	15.0
50		70	130	210	316	450	606	780	980	1200	15.0
60		80	150	244	370	314	690	890	1120	1380	15.0
Size E											
20 ton		20	52	96	144	208	272	340	430	528	18.8
25		24	56	104	176	256	340	432	540	648	18.8
30		26	60	120	200	300	410	520	660	800	18.8
35		40	80	160	246	360	484	608	756	908	18.8
40		44	90	180	290	424	580	746	950	1180	18.8
45		54	116	210	340	484	660	850	1080	1330	18.8
50		56	120	230	366	534	720	936	1200	1520	18.8
60	30	84	170	290	444	620	830	1074	1380	1740	18.8
Size F											
20 ton		44	80	134	186	250	320	390	470	546	22.4
25		48	90	154	220	300	392	480	586	694	22.4
30		60	114	190	276	368	480	590	716	840	22.4
35		76	148	226	324	440	560	690	840	980	22.4
40		80	152	252	370	516	692	880	1100	1332	22.4
45		100	184	300	436	600	796	1010	1248	1500	22.4
50		116	214	340	490	670	884	1120	1380	1632	22.4
60	40	120	226	372	548	760	1020	1320	1660	2040	22.4

241

	10	20	30	40	50	60	70	80	90	100	A_{max}
Size G											
30 ton	28	74	136	200	290	380	496	620	750	890	26.1
35	32	88	160	248	348	456	584	736	880	1050	26.1
40	56	124	220	336	468	600	780	976	1170	1400	26.1
45	68	150	260	386	540	696	890	1104	1320	1570	26.1
50	80	176	300	450	620	800	1028	1280	1540	1830	26.1
60	90	200	350	520	720	940	1216	1540	1880	2280	26.1
Size H											
40	44	110	200	320	460	630	830	1056	1300	1560	30.0
45	60	148	264	416	600	800	1024	1270	1520	1790	30.0
50	78	176	300	470	660	900	1154	1436	1740	2050	30.0
60	82	194	340	520	748	1020	1310	1650	2020	2420	30.0
Size I											
50	124	166	420	610	820	1056	1310	1560	1956	2150	33.6
60	140	296	476	680	920	1200	1500	1800	2150	2530	33.6

Table I-C-2: GENERAL TIRE & RUBBER - RAYKIN
CURVE COEFFICIENTS

$$K = a + b\Delta \text{ or}$$
$$= a + b\Delta + c\Delta^2$$

Δ = inches
K = kips/inch

	a	b	c	boundary lower	upper
Size C					
20 ton	5.66	-.026		0	11.2
25	7.26	-.066		0	11.2
30	9.10	-.090		0	11.2
35	10.50	-.092		0	11.2
40	11.94	-.056		0	11.2
45	13.38	-.064		0	11.2
50	13.96	-.020		0	11.2
60	16.80			0	11.2
Size D					
20 ton	4.38	-.026		0	15.0
25	5.50	-.038		0	15.0
30	7.08	-.072		0	15.0
35	8.10	-.074		0	15.0
40	9.20	-.066		0	15.0
45	10.26	-.072		0	15.0
50	11.08	-.054		0	15.0
60	12.86	-.054		0	15.0
Size E					
20 ton	3.76	-.066		0	18.8
25	4.64	-.078		0	18.8
30	5.90	-.100		0	18.8
35	6.76	-.110		0	18.8
40	7.36	-.054		0	18.8
45	8.26	-.056		0	18.8
50	9.64	-.076		0	18.8
60	10.60	-.076		0	18.8
Size F					
20 ton	4.511	-.147	.002	0	22.4
25	5.715	-.188	.003	0	22.4
30	5.691	-.214	.004	0	22.4
35	6.536	-.359	.004	0	22.4
40	7.978	-.303	.007	0	22.4
45	8.786	-.317	.007	0	22.4
50	9.438	-.351	.009	0	22.4
60	10.72	-.339	.009	0	22.4

	a	b	c	boundary	
				lower	upper
Size G					
30 ton	4.96	-.114		0	26.1
35	5.42	-.114		0	26.1
40	5.48	-.080		0	26.1
45	6.14	-.086		0	26.1
50	6.70	-.066		0	26.1
60	7.52	-.044		0	26.1
Size H					
40 ton	5.32	-.088		0	30.0
45	6.18	-.106		0	30.0
50	6.36	-.088		0	30.0
60	7.10	-.086		0	30.0
Size I					
50 ton	5.78	-.082		0	33.6
60	6.92	-.098		0	33.6

General Tire
Size C - Raykin Fenders

60 ton

50 ton
45 ton

40 ton

35 ton
30 ton

25 ton

20 ton

Stiffness (k) - kips per inch

20.0

16.0

12.0

8.0

4.0

0   2.0   4.0   6.0   8.0   10.0   12.0   14.0

Deflection (Δ) - inch
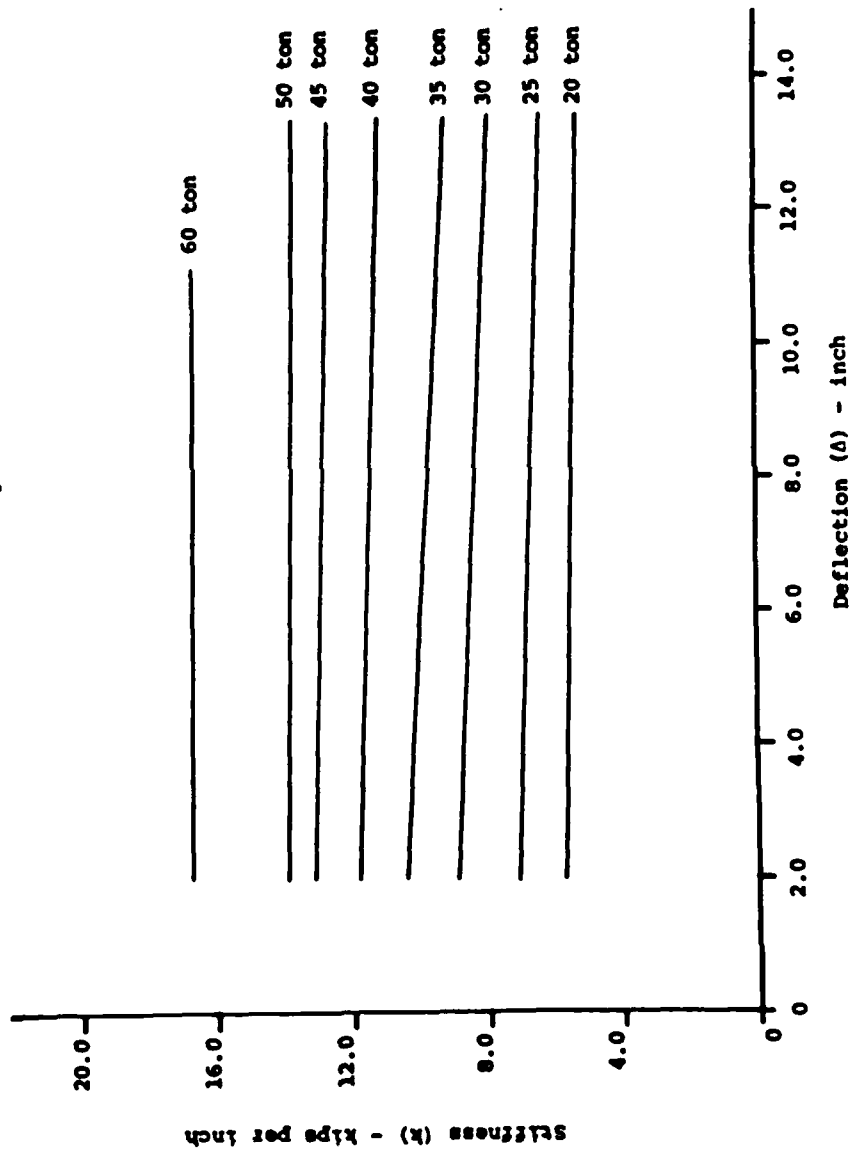
FIG. I-C-1: Stiffness vs. Deflection for General Tire Size C-Raykin Fenders

General Tire
Size D – Raykin Fenders

60 ton

50 ton
45 ton
40 ton

35 ton
30 ton
25 ton
20 ton

Deflection (Δ) – inch

Stiffness (K) – kips per inch
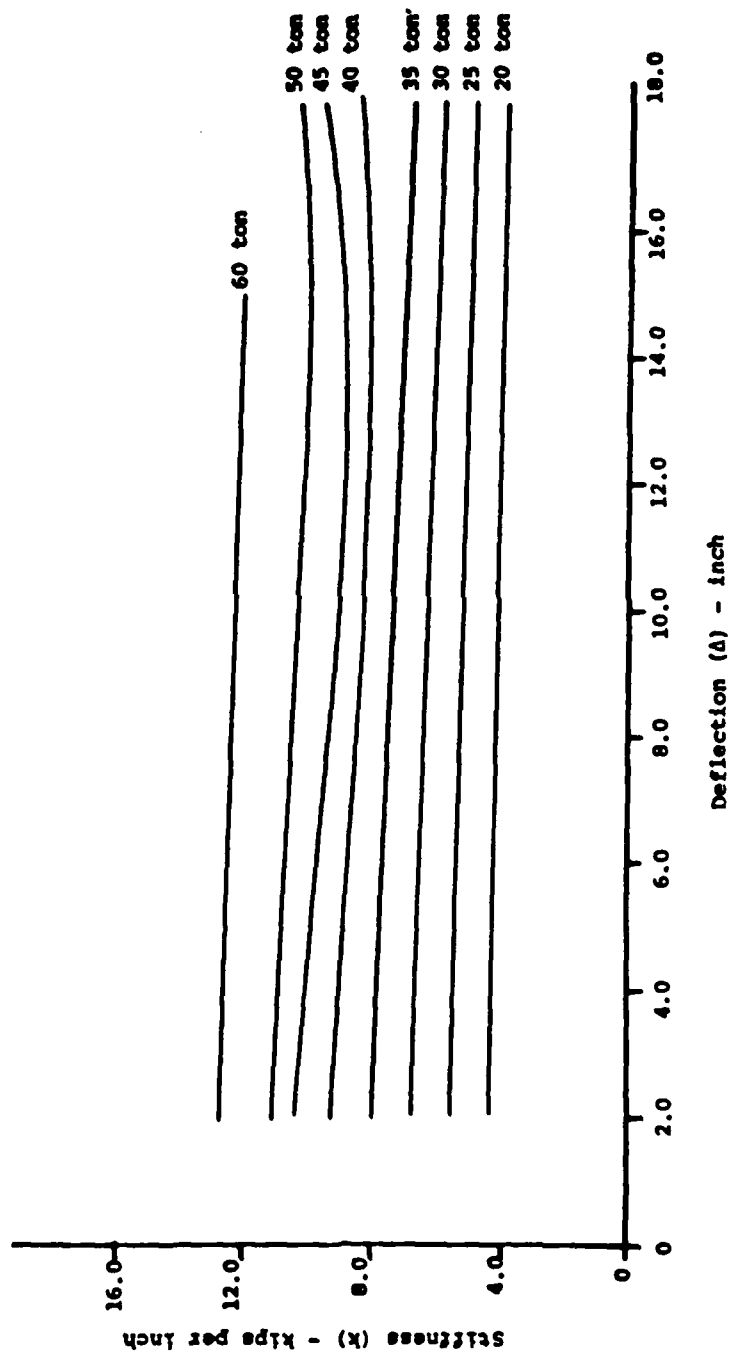
FIG. I-C-2: Stiffness vs. Deflection for General Tire Size D-Raykin Fenders

General Tire
Size E – Raykin Fender

Stiffness (K) – kips per inch

Deflection (Δ) – inch

60 ton
50 ton
45 ton
40 ton
35 ton
30 ton
25 ton
20 ton
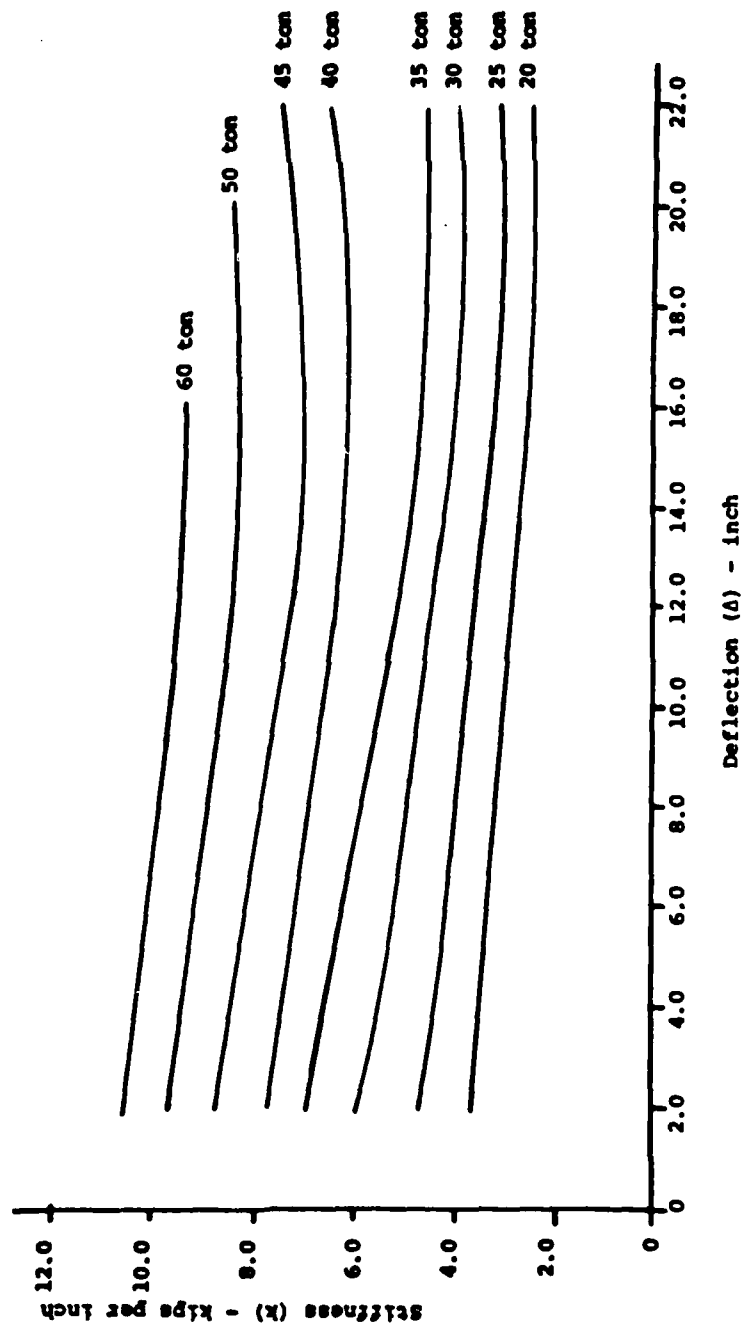
FIG. I-C-3: Stiffness vs. Deflection for General Tire Size E-Raykin Fenders

247

General Tire
Size F – Raykin Fender

FIG. I-C-4: Stiffness vs. Deflection for General Tire Size F-Raykin Fenders
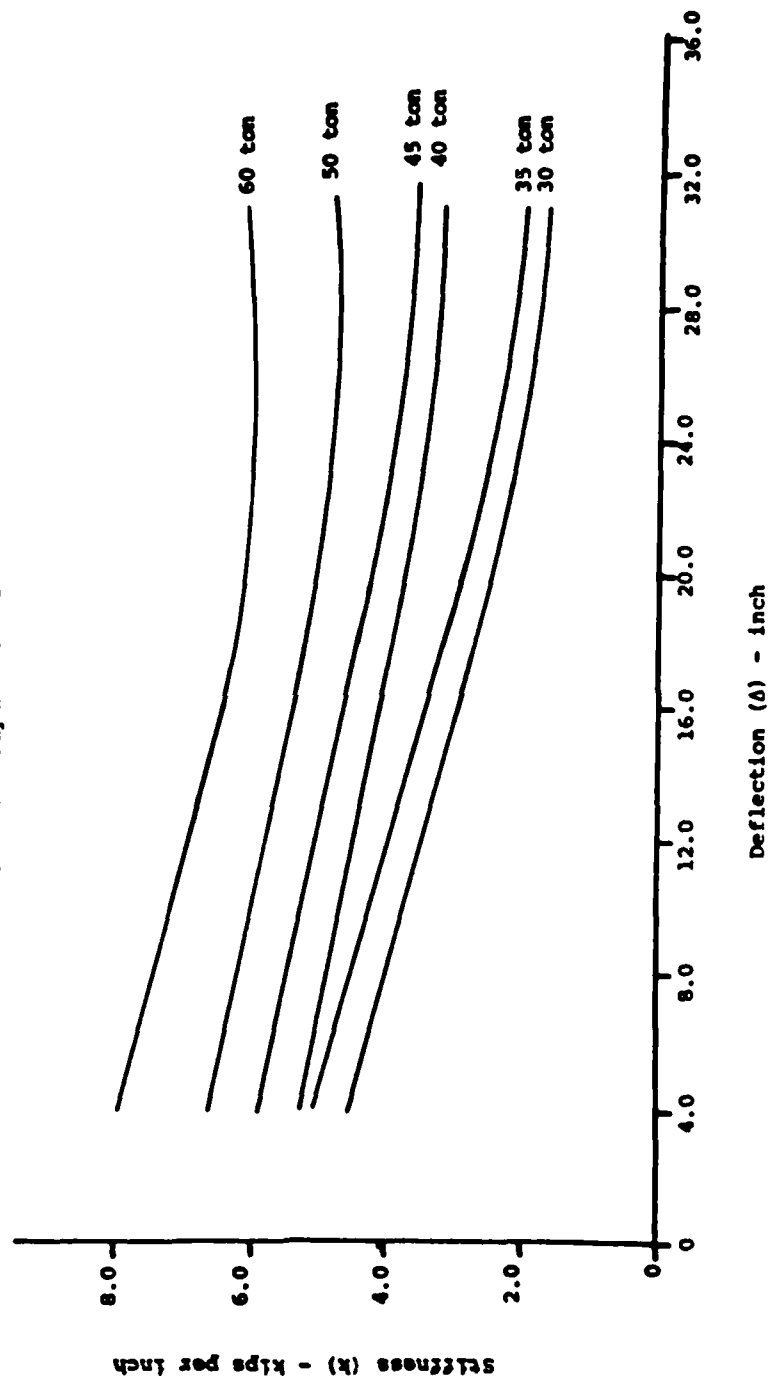
248

General Tire
Size G - Raykin Fender

Stiffness (k) - kips per inch

Deflection (Δ) - inch

FIG. I-C-5: Stiffness vs. Deflection for General Tire SizeG-Raykin Fenders

249

General Tire
Size H - Raykin Fender

60 ton
50 ton
45 ton
40 ton

Deflection (Δ) - inch

Stiffness (k) - kips per inch
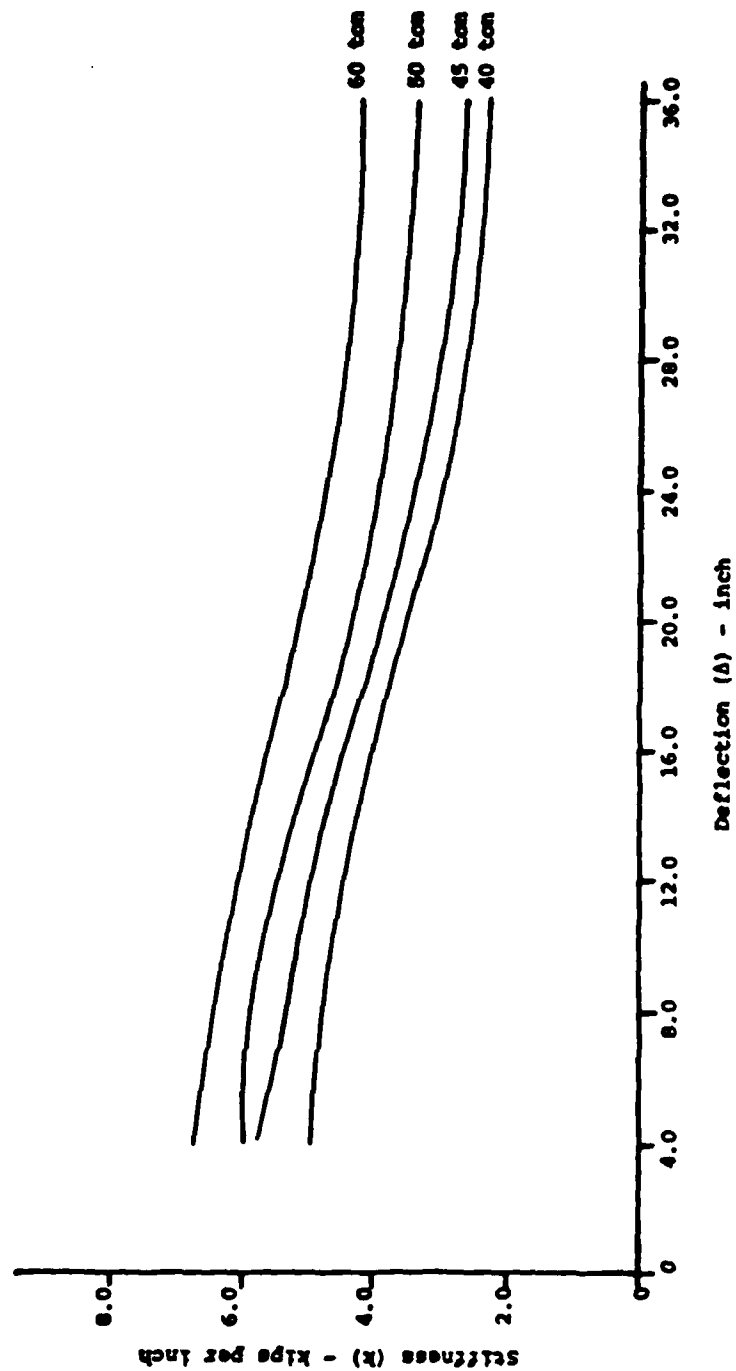
FIG. 1-C-6: Stiffness vs. Deflection for General Tire Size H-Raykin Fenders

250

General Tire
Size I - Raykin Fender
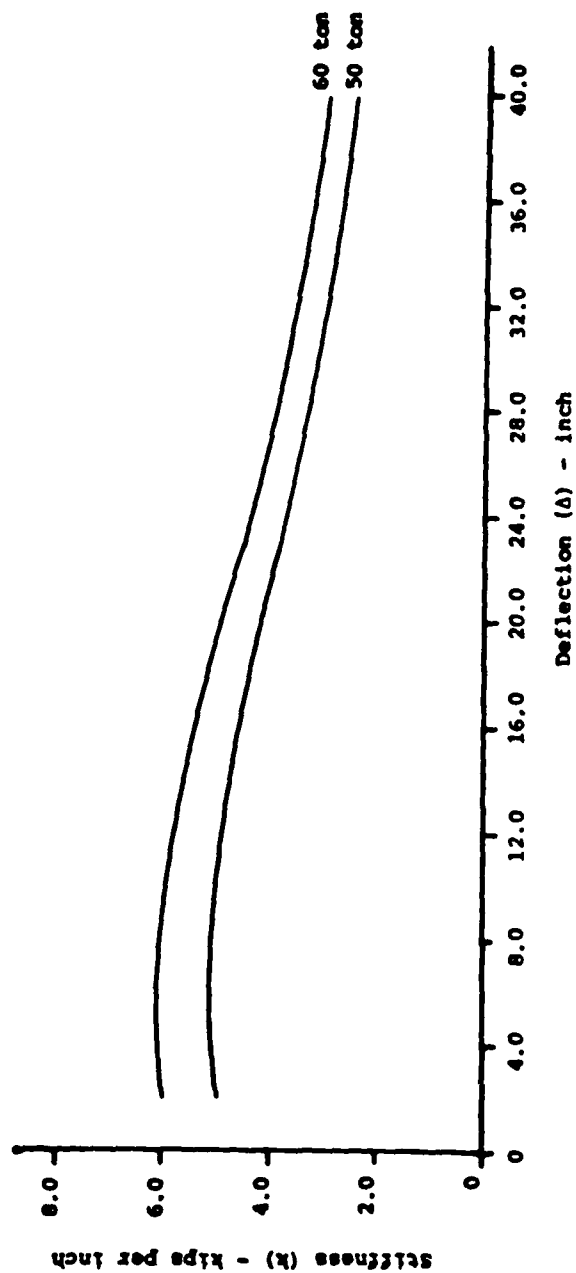
FIG. I-C-7: Stiffness vs. Deflection for General Tire Size I-Raykin Fenders

251

APPENDIX I-D

GOODYEAR TIRE AND RUBBER COMPANY

Table I-D-1: GOODYEAR ENERGY TABLES

K = Kip-in./foot of length

Rectangular	10	20	30	40	50	60	70	80	90	100	Δ_{max}
2x4x0								14		24	1.25
3.5x4.5x1					6.0	12	22	26	48	60	2.10
5x6.5x2.5				3.6	6.0	13	19	32	56	79	3.10
7x10x3		2.4	6.0	14.4	29	42	62	82	112	163	4.00
8x10x3		1.2	2.4	12.0	18	26	36	56	84	132	4.50
8x8x3		1.2	2.4	12.0	20	34	46	65	90	120	4.75
10x10x4		1.2	8.4	15.6	28	46	60	90	144	214	5.50
10x12x4		2.4	12.0	20.4	29	46	61	101	142	209	6.00
12x12x5		2.4	12.0	24.0	41	58	90	125	170	246	6.75
14x14x6		4.8	18.0	31.2	60	82	120	162	236	336	7.75
20x20x8		8.4	20.4	39.6	62	91	127	166	212	281	8.50

D-Fenders	Kip-in/foot of length										
6"		1.2	1.6	2.4	3.0	5.8	7.2	9.6	18	40	4.0
8"		1.2	2.4	3.6	6.0	9.0	13	17	28	53	5.5
12"		1.8	3.6	7.2	13.0	16	22	30	44	70	7.2

Trapezoid	Kip-in./foot of length										
10"	2.4	.6	8.4	23	16	20	28	32	37	48	4.6
13"	4.8	.7	12	17	26	30	40	54	66	72	6.0
15"	6.0	12	18	25	35	46	55	70	83	96	6.6
17"	6.0	14	24	34	47	60	77	91	110	127	7.6
20"	7.2	18	30	46	64	82	101	122	144	166	8.7

Cyl. End Ld.	Kip-in/foot of length				Δ_{max} = 50% of max. length						
10					24	36	48	72	96	120	7.5
12			12	24	60	84	96	144	180	216	9.0
15		24	36	60	96	144	204	252	324	396	11.5
18		36	60	108	168	252	336	432	528	648	13.2
21		48	96	168	276	396	528	1032	828	1020	15.5
24		60	120	204	300	408	540	696	864	1020	15.0
27		60	108	180	264	360	480	600	744	900	13.2

253

								Kip-in/foot length			
Cylindrical	10	20	30	40	50	60	70	80	90	100	A_{max}
3"							3.6	9.6	17	32	2.25
5"				2.4	2.4	3.6	4.8	6.0	12	28	3.5
7"			2.4	2.4	3.6	6.0	7.2	9.6	20	55	4.6
8"			2.4	3.6	6.0	8.4	9.6	16	31	59	5.4
10"		1.2	2.4	4.8	7.2	9.6	13	16	30	60	6.0
12"		2.4	3.6	6.0	9.6	13	17	22	36	72	7.0
15"		2.4	4.8	9.6	13	18	24	28	42	84	8.5
18"	1.2	3.6	7.2	12	18	26	34	41	59	108	10.5
21"	1.2	4.8	8.4	16	23	31	40	53	72	131	11.8
24"	1.2	6.0	11	18	26	36	48	62	80	140	13.0
27"	1.2	6.0	13	22	30	43	56	74.4	104	163	14.25
36"		1.2	24	48	60	84	108	156	216	300	21.0
48"		1.2	36	60	96	144	204	252	348	480	27.0
60"		2.4	48	84	132	192	264	360	480	648	31.0

Wing Type								Kip-in/foot of length			
3x1x6x7.5				2.4	3.6	4.8	6.0	9.0	11	19	1.75
4x1x6.5x1				2.4	4.8	7.2	8.4	12	22	26	2.10
4x2x6.5x1				3.6	4.8	6.0	9.6	16	28	57	2.50
6x2x9.5x1.5			3.6	7.2	9.6	13	19	28	36	60	3.3
6x3x9x1.5	1.2	3.6	4.8	6.0	7.2	9.6	13	22	37	84	4.0
10x3x16x2.5	1.2	3.6	7.2	12	17	24	32	43	64	96	4.7
10x4x16x2.5	1.2	3.6	7.2	12	18	24	32	43	61	94	5.0
8x4x12x2	1.2	3.6	6.0	7.2	8.4	12	16	22	38	67	4.6
12x6x18x3	2.4	4.8	7.2	9.6	13	18	23	32	50	94	6.5

Win

6x2
10x
10x
6x3
8x4
12x

Cyl

5"
8"
10"
12"
15"
18"
21"
24"
27"
36"
48'
60"

Cy:

10>
12>
15>
18:
21:
24.
27.

Table I-D-2: GOODYEAR CURVE COEFFICIENTS

Rectangular $\quad K = a + b + c^2$ or $\qquad\qquad K = $ kips/inch/ft of length
$\qquad\qquad\quad$ = constant = d

	a	b	c	boundary lower	upper	d	boundary lower	upper
2x4x0	37.33	-52.00	58.67	.5	1.25			
3.5x4.5x1	35.50	-40.25	23.75	1.0	2.0			
5x6.5x2.5	35.19	-41.58	14.40	1.0	3.0			
7x10x3	29.64	-15.98	4.33	2.0	4.0			
8x10x3	19.36	-12.52	3.17	2.0	4.0			
10x10x4	13.08	- 6.13	1.54	2.0	5.0			
8x8x3	18.14	- 9.73	2.08	2.0	4.0			
10x12x4	52.00	-25.50	3.50	3.0	6.0	7.0	2.0	3.0
12x12x5	21.40	- 8.40	1.20	4.0	6.0	7.0	2.0	4.0
14x14x6	11.27	- 3.20	.533	4.0	7.0	7.0	2.0	4.0
20x20x8	20.68	- 5.34	.510	6.0	8.0	7.0	2.0	6.0

D Fenders $\qquad K = a + b\Delta + c\Delta^2$ $\qquad\qquad\qquad K = $ kips/foot of length

	a	b	c	boundary lower	upper
6 inch	41.25	-34.13	7.13	2.0	4.0
8 inch	7.100	- 4.73	.967	2.0	5.0
12 inch	3.58	- 1.76	.363	2.0	7.0

Regular and Wing Type Trapezoidal $\qquad K = a + b\Delta$ or $\qquad$ K/foot of length
$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad$ = a' + b'\Delta + c'\Delta^2

	a	b	boundary lower	upper	a'	b'	c'	boundary lower	upper
10"					7.53	- 1.56	.145	2.0	4.0
13"	4.66	+ .170	2.0	3.0	11.35	- 2.83	.255	3.0	5.0
15"	4.00	+ .500	2.0	3.0	10.75	- 2.32	.190	3.0	6.0
17"	4.00	+ .500	2.0	3.0	8.51	- 1.22	.074	3.0	7.0
20"	4.00	+ .500	2.0	4.0	10.49	- 1.36	.058	4.0	8.0

255

Wing Type Cylindrical $K = a + b\Delta$ or   K/foot of length
$\qquad = a' + b'\Delta + c'\Delta^2$

	a	b	boundary lower	boundary upper	a'	b'	c'	boundary lower	boundary upper
6x2x9.5	6.0	0	1.0	1.5	17.27	-13.87	4.26	1.5	3.0
10x3x16	6.0	0	1.0	2.5	10.00	- 3.43	.733	2.5	4.0
10x4x16	6.0	0	1.0	2.85	16.57	- 7.04	1.17	2.85	5.0
6x3x9	2.5	0	1.0	1.25	12.07	-12.98	4.10	1.25	3.0
8x4x12	2.5	0	1.0	3.25	25.90	-16.30	2.80	3.25	4.0
12x6x18	2.30	+.200	1.0	4.50	11.73	- 5.38	.764	4.50	6.0

Cylindrical $K = a + b\Delta$ or   K/foot of length
$\qquad = a' + b'\Delta + c'\Delta^2$

	a	b	boundary lower	boundary upper	a'	b'	c'	boundary lower	boundary upper
5"					3.55	- 3.75	1.30	2.0	3.0
8"	1.20	0	2.0	3.2	33.51	-19.48	2.93	3.2	5.0
10"	1.20	0	2.0	4.2	79.25	-35.66	4.06	4.2	6.0
12"	1.20	0	2.0	5.0	45.55	-18.35	1.90	5.0	7.0
15"	1.20	0	2.0	6.9	120.12	-35.33	2.62	6.9	8.0
18"	1.20	0	2.0	8.2	24.27	- 6.30	.424	8.2	10.0
21"	1.20	0	2.0	9.5	99.27	-20.72	1.09	9.5	11.0
24"	1.20	0	2.0	11.0	107.59	-19.54	.898	11.0	13.0
27"	1.20	0	2.0	12.0	92.14	-15.36	.650	12.0	14.0
36"	1.20	0	2.0	15.0	12.31	- 1.50	.050	15.0	20.0
48"	1.20	0	2.0	16.0	- .404	.125	-.002	16.0	24.0
60"	1.20	0	2.0	20.0	2.99	- .191	.005	20.0	30.0

Cylindrical: End-Loaded $K = $ Constant d   K/foot of length

	d	boundary lower	boundary upper
10x5	3.60	0	7.0
12x6	4.60	0	9.0
15x7.5	5.90	0	11.0
18x9	7.18	0	13.0
21x10.5	8.40	0	15.0
24x12	9.28	0	15.0
27x13.5	10.50	0	13.0

Goodyear Rectangular Fender
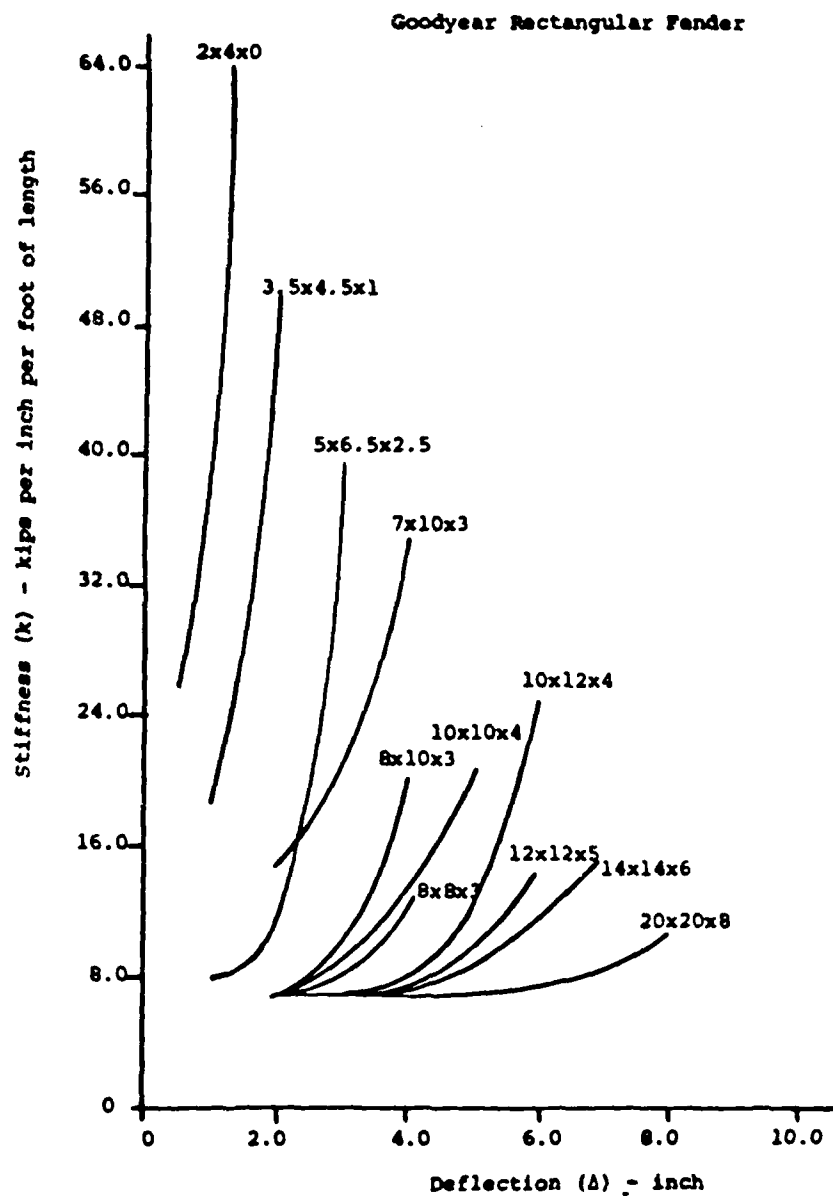
FIG. I-D-1: Stiffness vs. Deflection for Goodyear Rectangular Fenders

Goodyear D Fenders
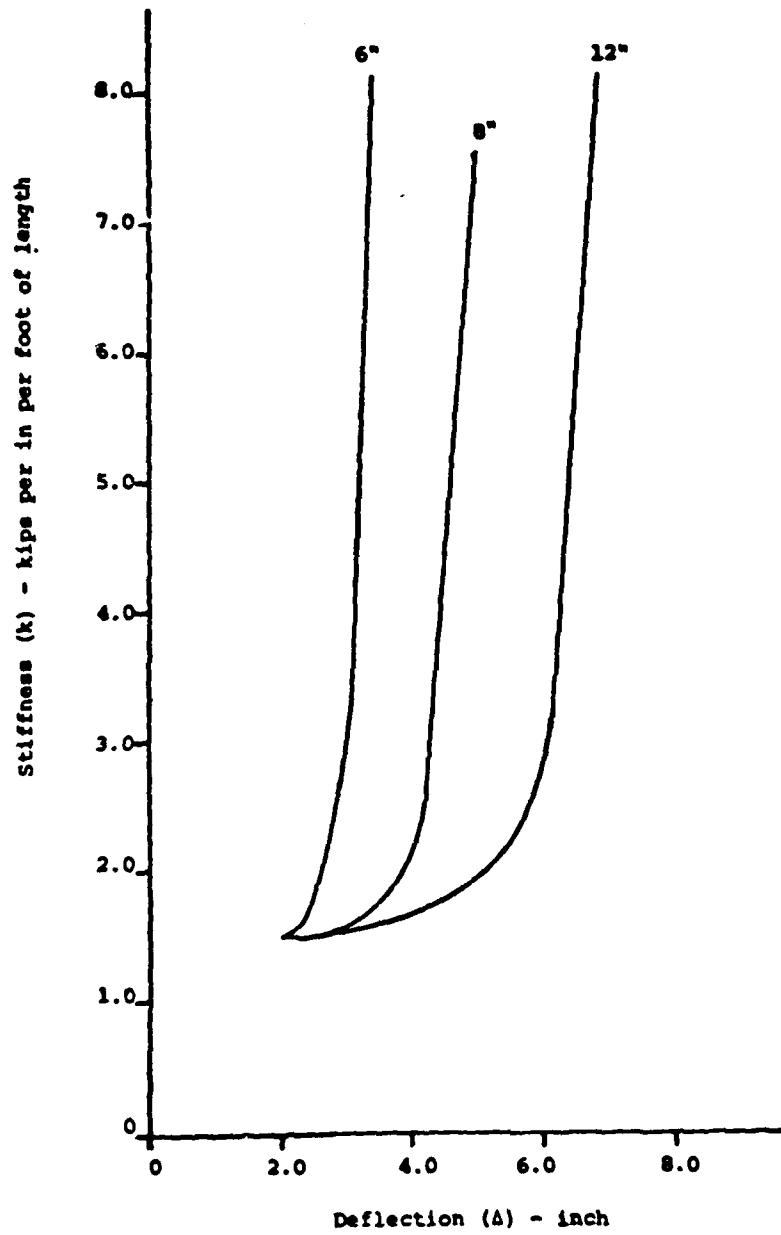
FIG. I-D-2: Stiffness vs. Deflection for Goodyear D-Fender

258

Goodyear Regular and Wing-type
Trapezoidal Fenders
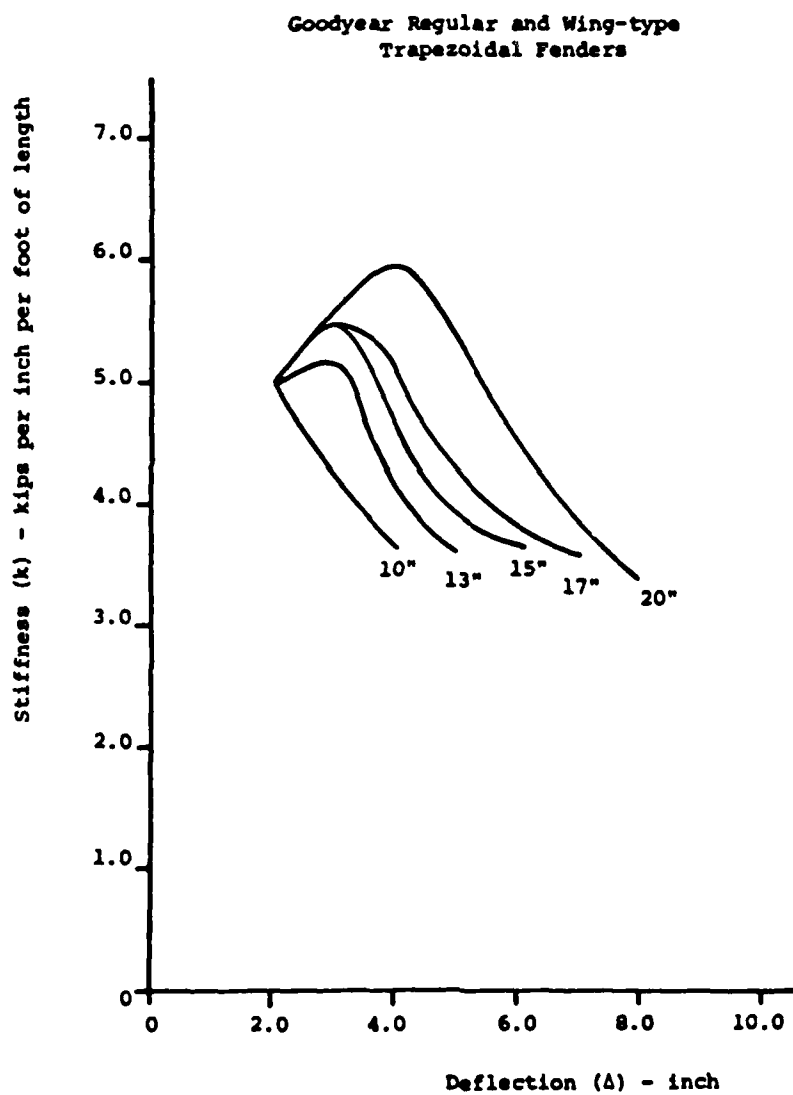
FIG. I-D-3: Stiffness vs. Deflection for Goodyear Regular and
Wing-type Trapezoidal Fenders

259

Goodyear Cylindrical Fenders
Axially Loaded
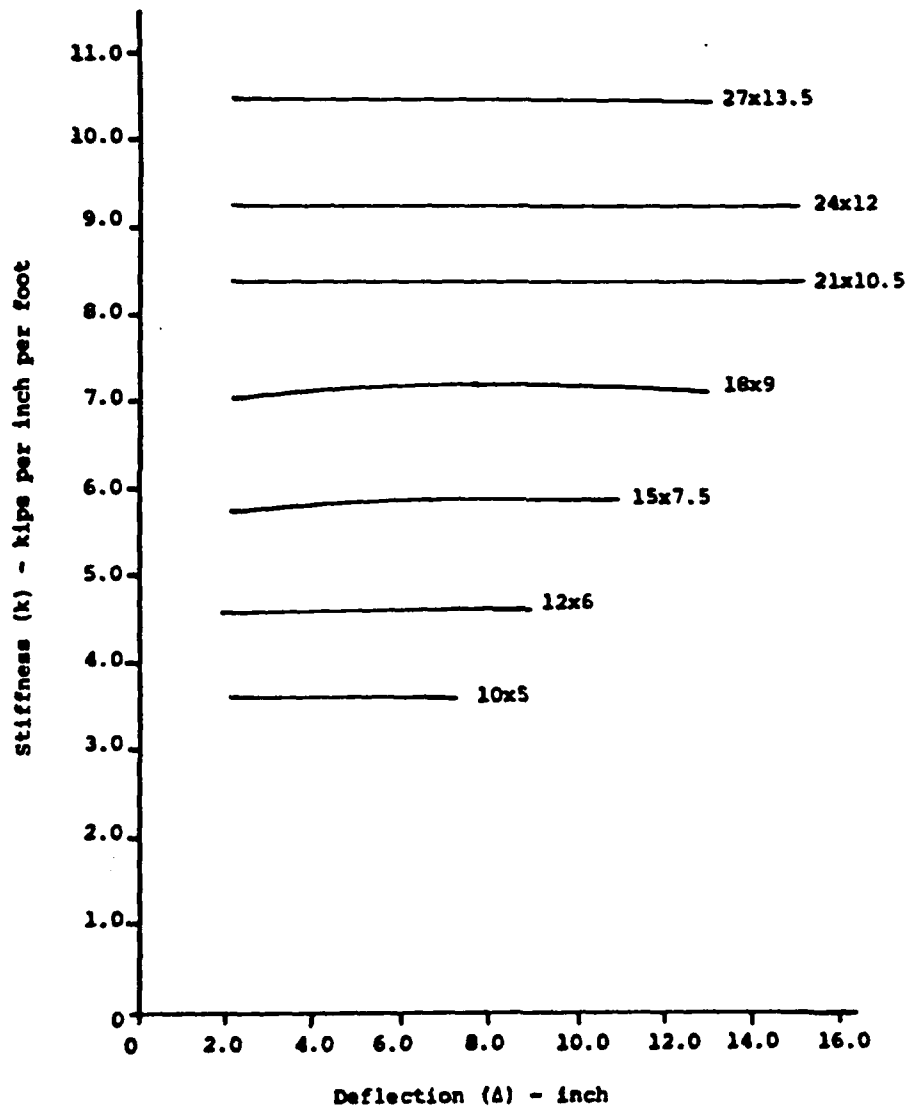
FIG. I-D-4: Stiffness vs. Deflection for Goodyear Cylindrical Fenders
Axially Loaded

260

Goodyear Cylindrical Fenders
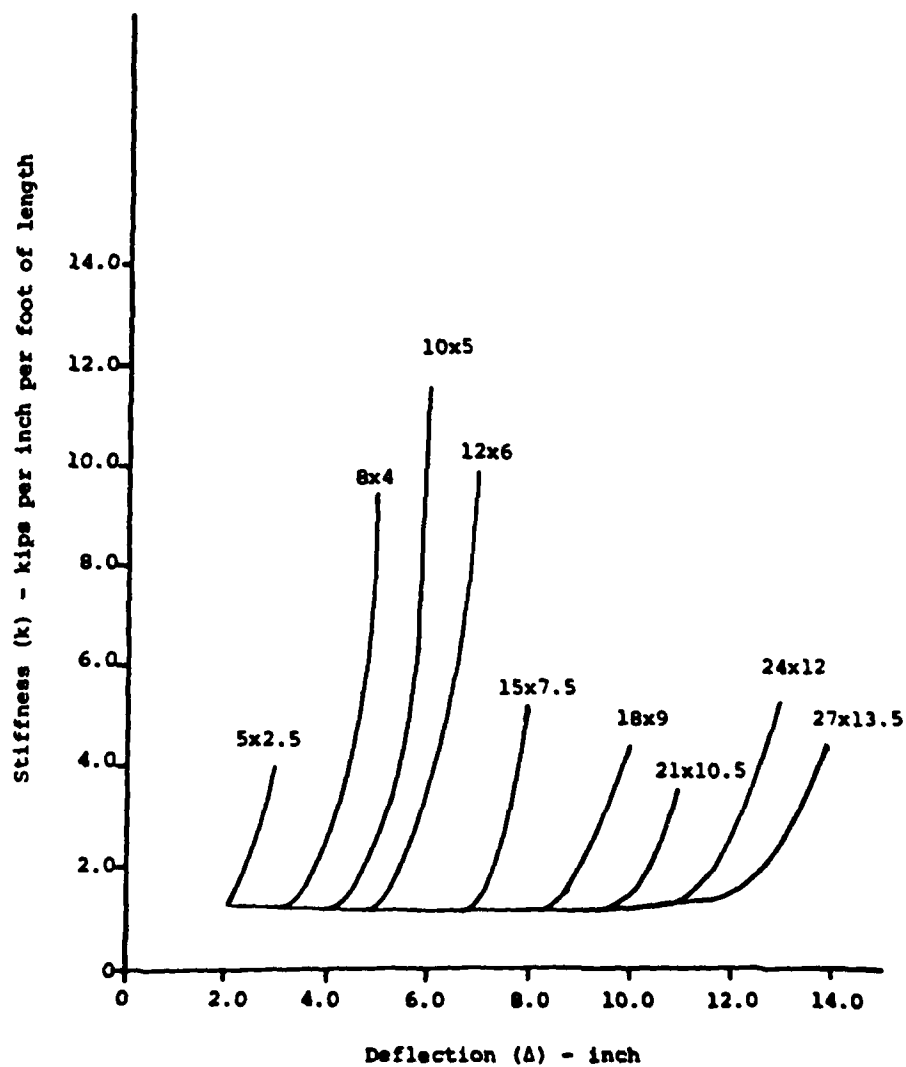
I-D-5: Stiffness vs. Deflection for Goodyear Cylindrical Fenders

Goodyear Giant Cylinder Fenders
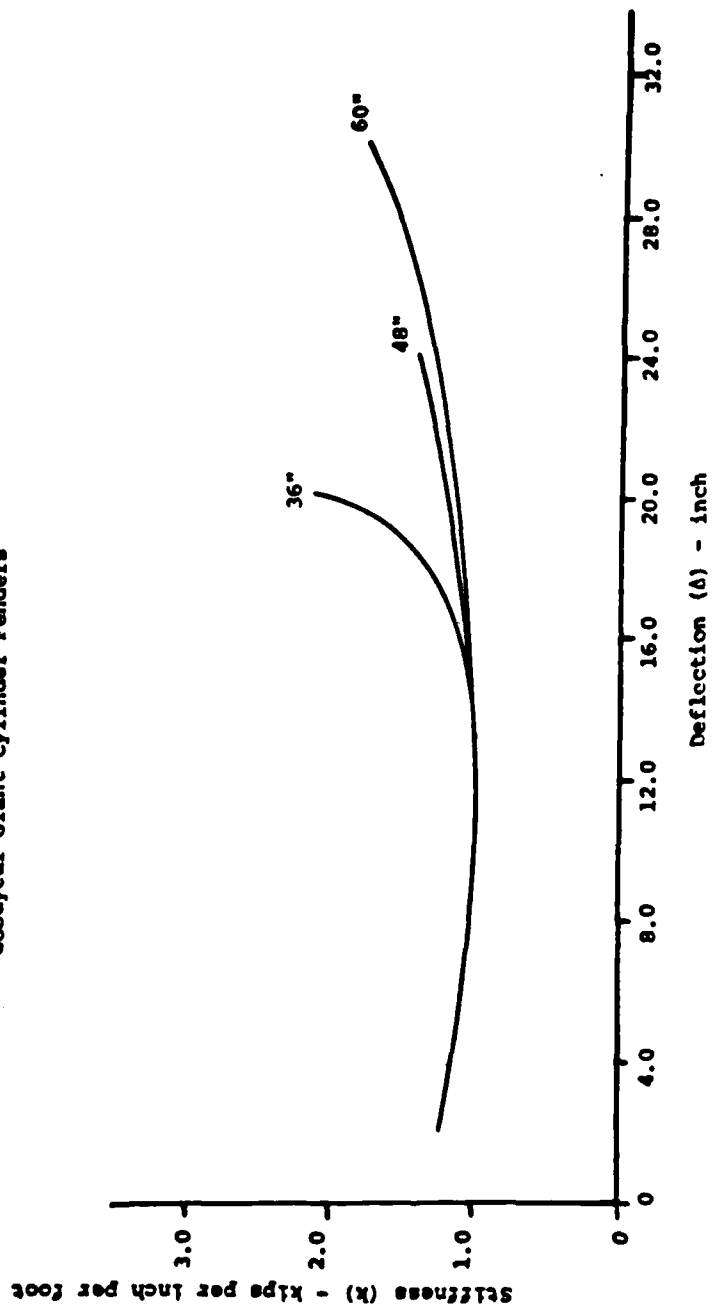
FIG. I-b-5: Stiffness vs. Deflection for Goodyear Giant Cylindrical Fenders

Goodyear Wing-type Cylindrical Fenders
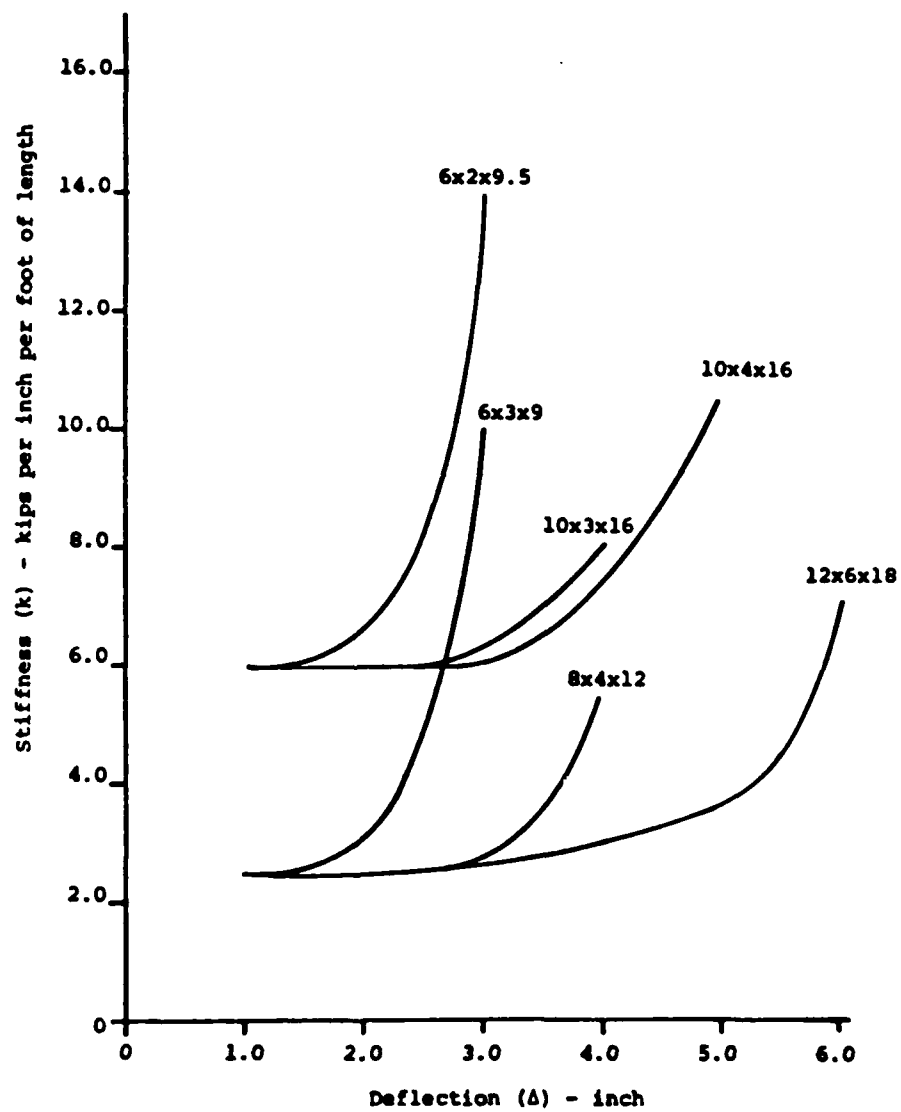
FIG. I-D-7: Stiffness vs. Deflection for Goodyear Wing-type
Cylindrical Fenders

Goodyear Portslide Fender
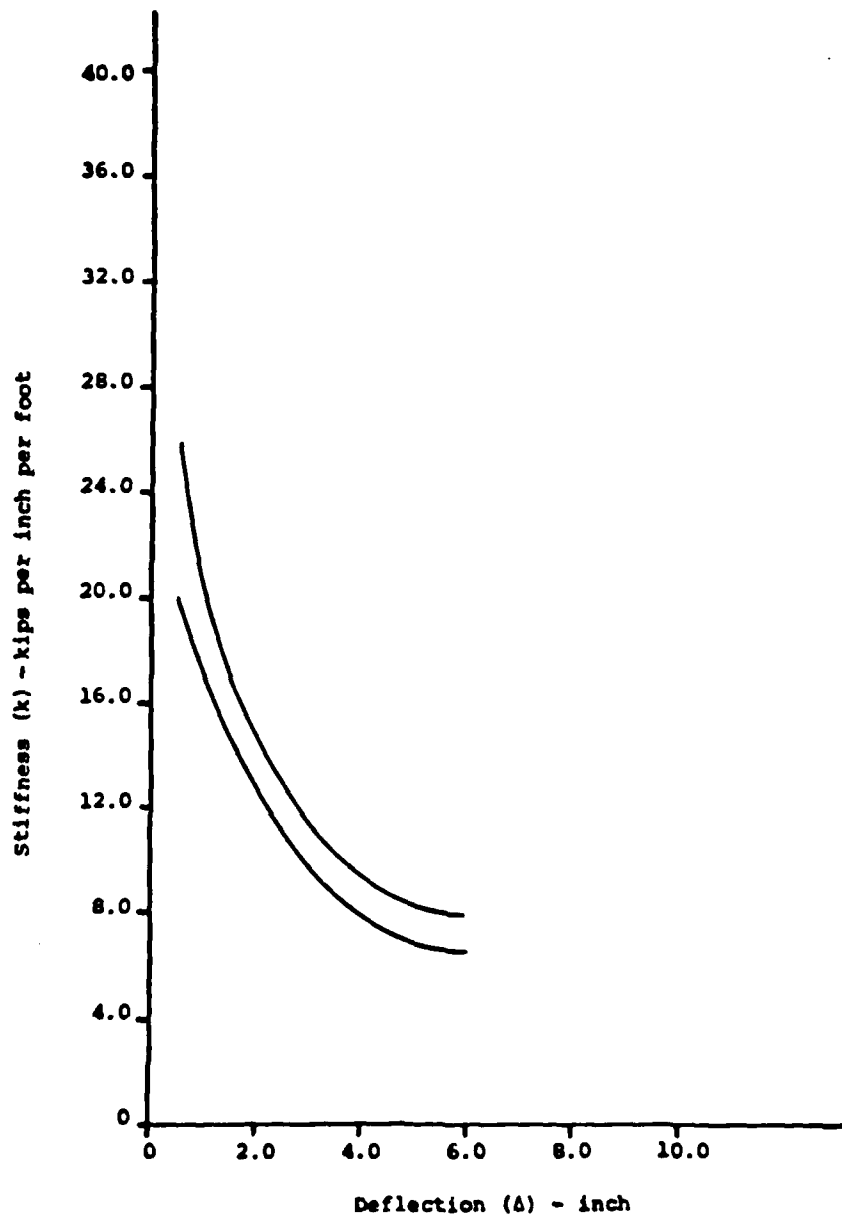
FIG. I-D-8: Stiffness vs. Deflection for Goodyear Portslide Fender

APPENDIX I-E

LORD CORPORATION

Table I-E-1: LORD ENERGY TABLE

	10	20	30	40	50	60	70	80	K = Kip-inches 90	100	Δ_{max}
1F4- 69			12	24	31	42	49	60	72	82	9.5
97			18	30	44	59	72	84	98	110	9.5
125			25	43	57	72	94	114	132	149	9.5
152			31	52	70	91	114	138	156	180	9.5
180			43	66	85	109	134	158	184	212	9.5
2F4-212				60	90	120	150	190	228	264	14.5
319				95	120	180	215	275	325	390	14.5
390				130	170	230	275	350	410	460	14.5
460				150	190	270	330	420	480	550	14.5
530				190	240	330	390	490	550	630	14.5
600				220	275	385	450	560	650	720	14.5
670				250	315	430	504	630	720	810	14.5
4F5- 14				3.0	5.4	7.2	9.6	12	15	18	5.5
21				5.5	7.8	11	14	18	22	26	5.5
28				7.2	10	14	19	23	28	33	5.5
35				9.0	13	19	23	29	36	42	5.5
47				12	18	24	31	38	48	58	5.5
5F- 600				200	275	360	455	540	635	720	23.0
765				240	360	445	565	685	810	890	23.0
900				300	444	540	660	820	960	1060	23.0
1070				360	515	660	816	960	1135	1260	23.0
1240				435	600	780	950	1105	1320	1450	23.0

Table I-E-2: LORD FENDER CURVE COEFFICIENTS

Lord Fender: $K = a + b\Delta + c\Delta^2$

1F4				boundary	
	a	b	c	lower	upper
69	3.79	− .431	.017	1.0	9.5
97	5.04	− .562	.023	1.0	9.5
125	6.89	− .934	.047	1.0	9.5
152	9.49	−1.60	.105	1.0	9.5
180	11.61	−1.69	.087	1.0	9.5
2F4					
212	4.70	− .371	.011	2.0	14.5
319	6.94	− .553	.017	2.0	14.5
390	8.45	− .707	.023	2.0	14.5
460	10.16	− .776	.022	2.0	14.5
530	13.05	−1.08	.033	2.0	14.5
600	17.16	−1.69	.057	2.0	14.5
670	21.95	−2.40	.085	2.0	14.5
4F5					
14	2.29	− .535	.050	1.0	5.0
21	3.13	− .515	.030	1.0	5.0
28	5.17	−1.35	.133	1.0	5.0
35	7.52	−2.27	.248	1.0	5.0
47	7.69	−2.00	.213	1.0	5.0
5F					
600	5.70	− .390	.020	2.0	10.0
765	7.95	− .715	.040	2.0	10.0
900	10.25	− .978	.051	2.0	10.0
1070	13.42	−1.19	.048	2.0	10.0
1240	18.22	−1.74	.064	2.0	10.0
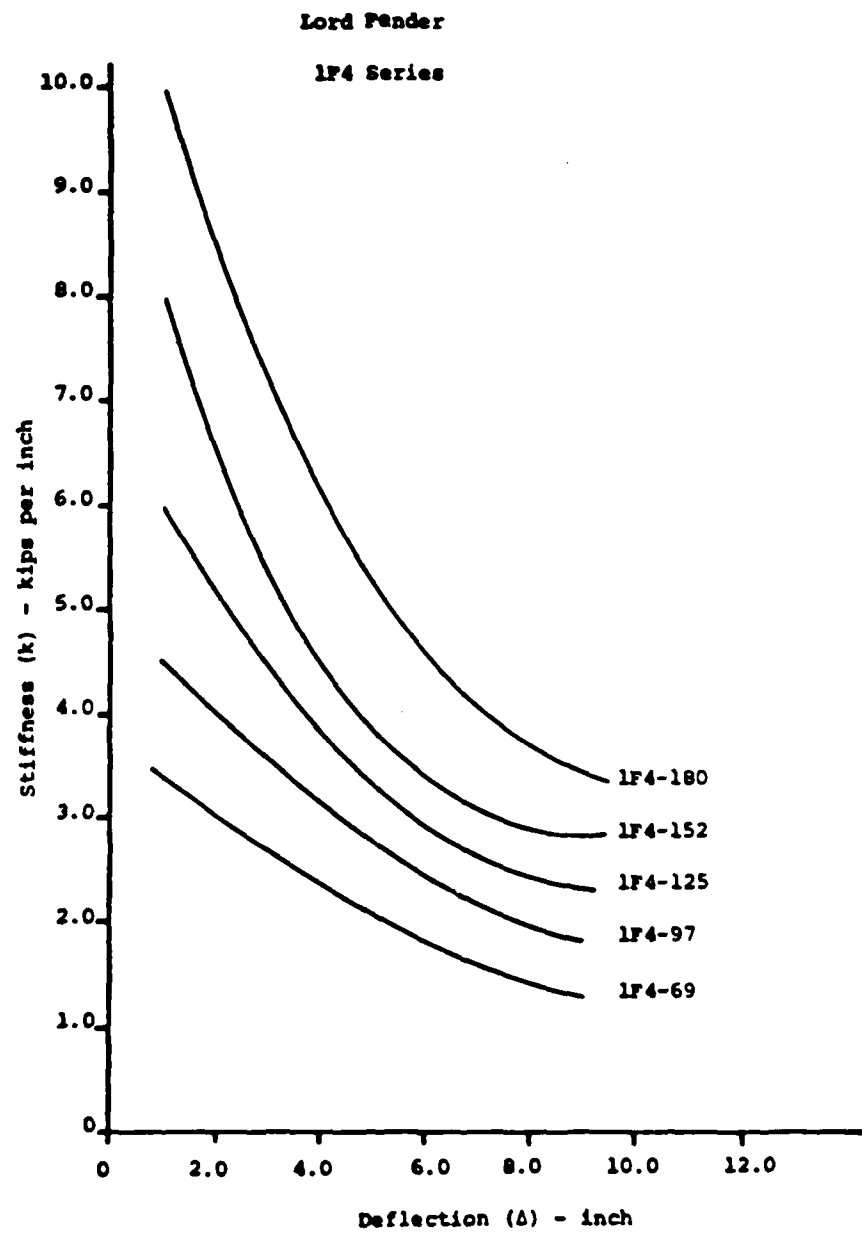
FIG. I-E-1: Stiffness vs. Deflection for Lord Fender 1F4 Series

268
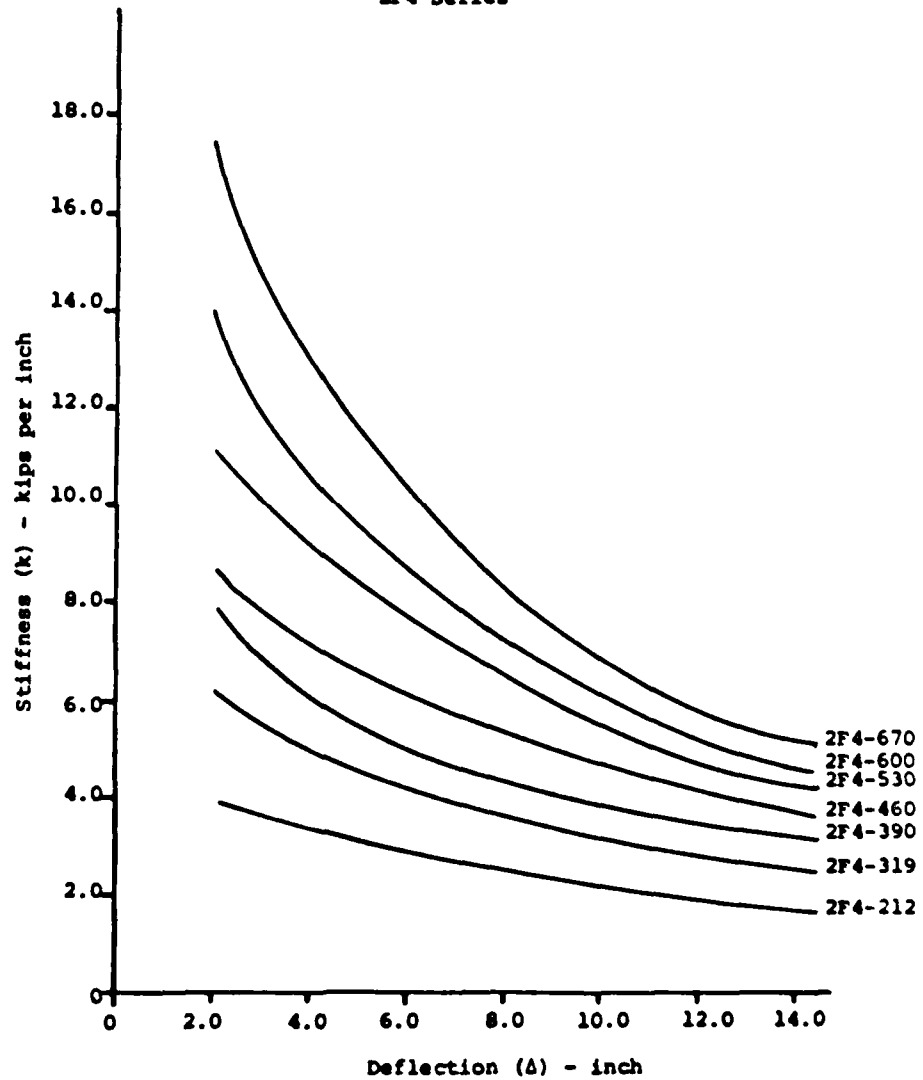
FIG. I-E-2: Stiffness vs. Deflection for Lord Fender 2F4 Series

269

Lord Fender
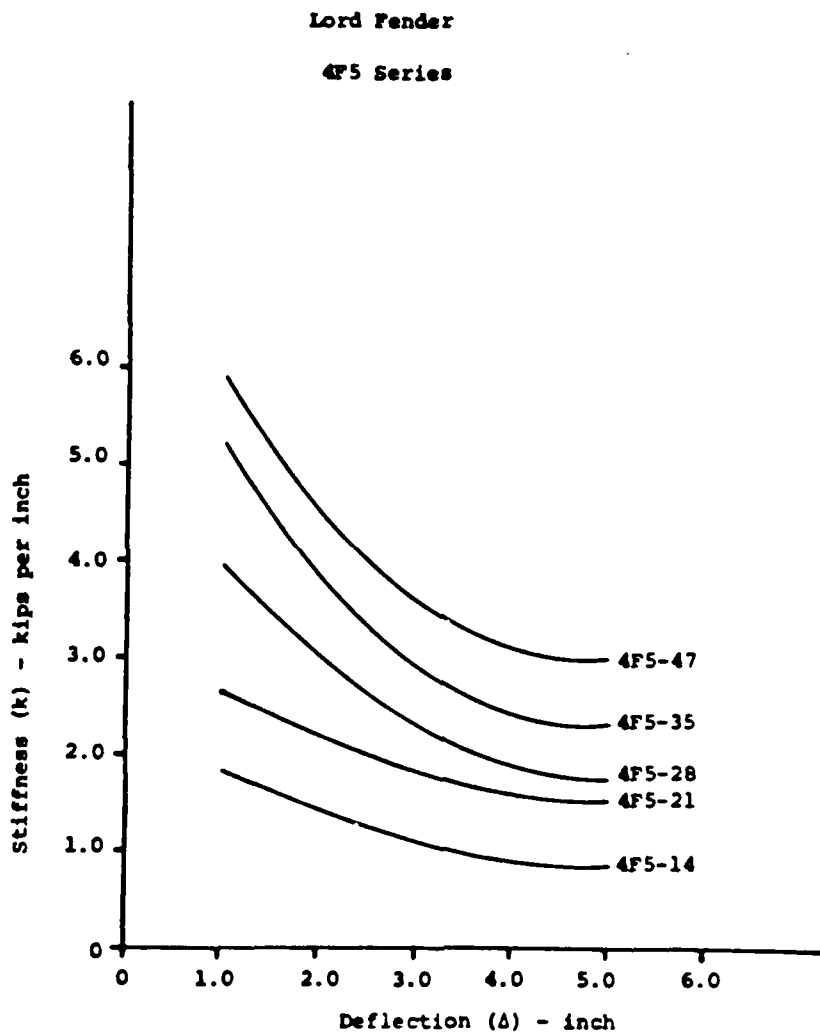
4F5 Series

FIG. I-E-3: Stiffness vs. Deflection for Lord Fender 4F5 Series
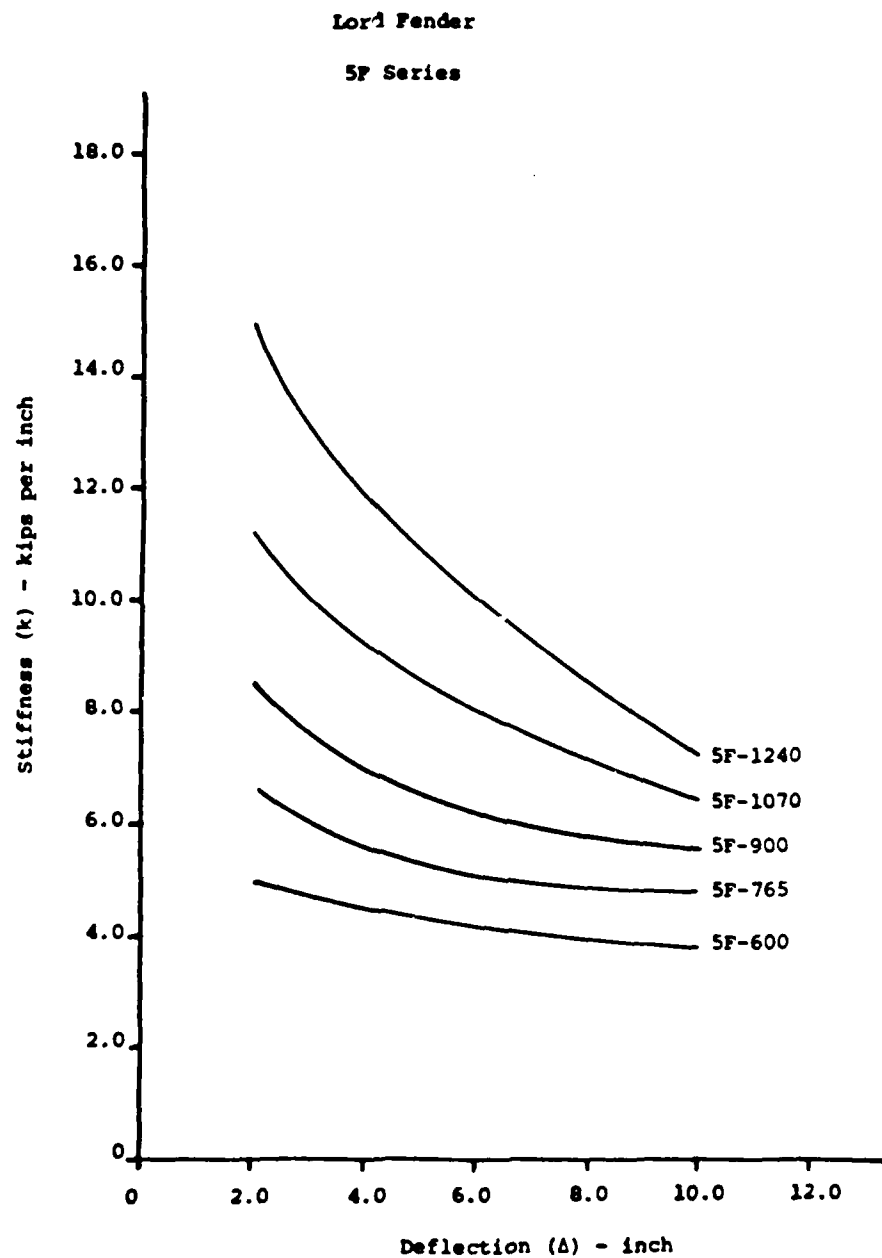
Lord Fender

5F Series

FIG. 1-2-4: Stiffness vs. Deflection for Lord Fender 5F series

271
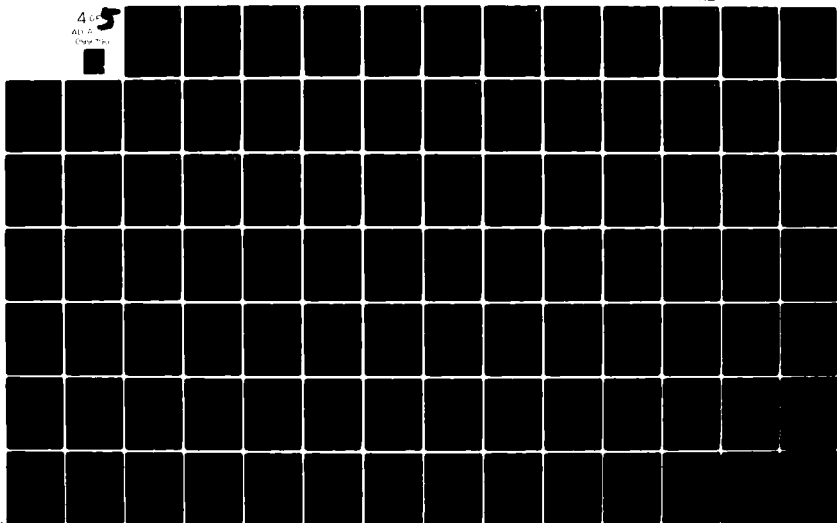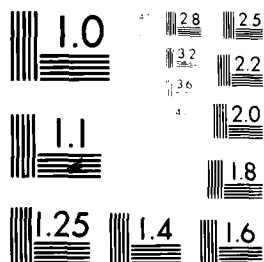
APPENDIX I-F

OIL STATES RUBBER COMPANY

Table I-F: OIL STATES
CURVE COEFFICIENTS AND ENERGY TABLE

Oil States Boat Bumpers $K = a + b\Delta + c\Delta^2$

a	b	c	boundary lower	upper
12.88	-8.2	18.8	1.25	.25

10	20	30	40	50	60	70	Kip-in./foot 80	90	100	Δ_{max}
	.75	1.75	337	5.90	9.73	15.40	23.48	34.74	50	1.25

Oil States
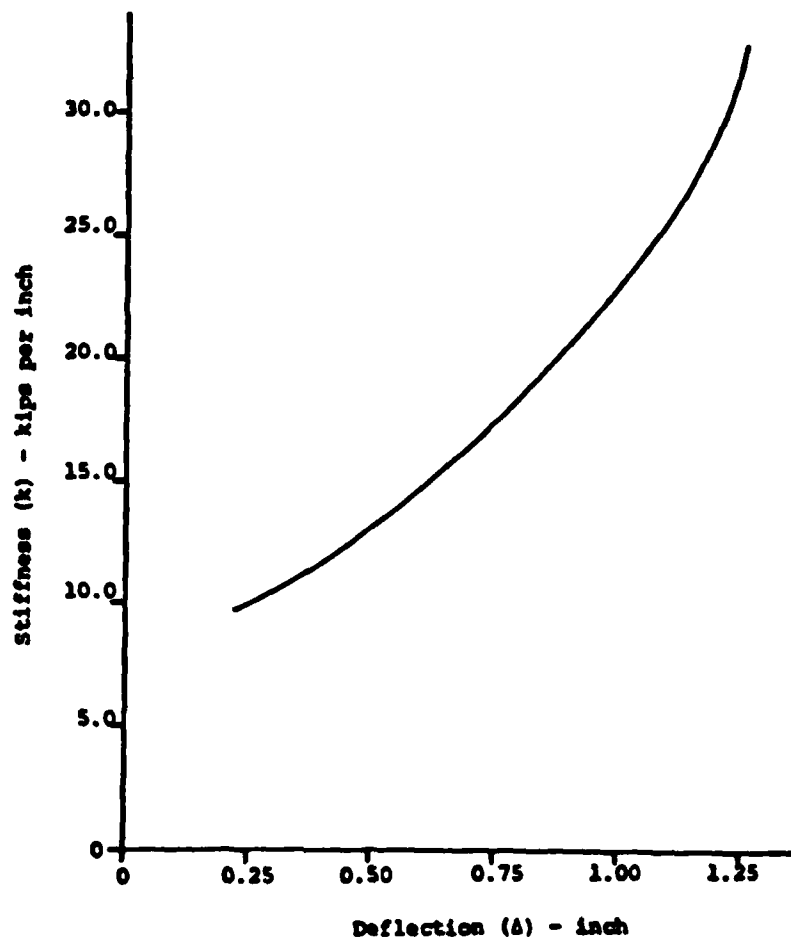
FIG. I-F: Stiffness vs. Deflection for Oil States Fender

APPENDIX I-G

SAMSON OCEAN SYSTEMS, INC.

Table I-G-1: SAMSON ENERGY TABLE

	10	20	30	40	50	E = Kip-inch 60
6x8	75	200	375	700	900	2040
6x12	120	280	520	1025	1800	3120
6x18	180	400	900	1600	2700	4680
8x12	200	400	960	2160	3180	5400
8x16	240	720	1440	2640	4200	7320
8x20	400	810	1700	3150	5100	9480
10x16	430	1030	2230	4000	6600	11500
10x20	360	960	2400	4320	7200	13200

Table I-G-2: SAMSON CURVE COEFFICIENTS

Solid Foam $K = a + b\Delta$ or
$= a' + b'\Delta + c'\Delta^2$ K = Kips per inch

	a	b	boundary lower	boundary upper	a'	b'	c'	boundary lower	boundary upper
10x20	.1478	.0003	24.0	56.0	.900	– .0262	.0002	56.0	72.0
4x8	---	---	--	--	.207	– .0049	.0002	7.0	28.5

Cost Fender $K = a + b\Delta$ or
$= a' + b'\Delta + c'\Delta^2$

	a	b	boundary lower	boundary upper	a'	b'	c'	boundary lower	boundary upper
2'x3'									
32"x4'	.656	.0139	3.0	14.0	3.011	– .355	.0143	14.0	19.0
32"x6'	1.0	---	3.0	9.5	2.313	– .255	.0123	9.5	19.0
4'x6'	1.017	.0067	5.0	20.0	4.40	– .350	.0094	20.0	29.0
4'x8'	1.233	.0133	5.0	20.0	6.987	– .565	.0146	20.0	29.0
4'x10'	1.633	.0133	5.0	20.0	8.817	– .707	.0181	20.0	29.0

Sprayed Fender $K = a + b\Delta$ or
$= a' + b'\Delta + c'\Delta^2$

	a	b	boundary lower	boundary upper	a'	b'	c'	boundary lower	boundary upper
6x8	1.574	.018	7.0	32.0	16.150	– .904	.0146	32.0	43.0
6x12	2.670	.0114	7.0	29.0	5.925	– .301	.0068	29.0	43.0
6x18	3.878	.0174	7.0	30.0	17.38	– .920	.0162	30.0	43.0
8x12	2.467	.0133	9.0	40.0	28.317	–1.241	.0152	40.0	57.0
8x16	3.400	---	9.0	24.0	6.063	– .200	.0037	24.0	57.0
8x20	4.196	.0104	9.0	34.0	13.540	– .533	.0079	34.0	57.0
10x16	3.300	.0083	12.0	48.0	6.374	– .193	.0029	48.0	72.0
10x20	4.300	.0083	12.0	48.0	12.76	– .403	.0049	48.0	72.0

Samson Solid Foam Fenders

10'x20'

4'x8'

Stiffness (K) - kips per inch

.30

.20

.10

0   8.0   16.0   24.0   32.0   40.0   48.0   56.0   64.0   72.0

Deflection (Δ) - inch
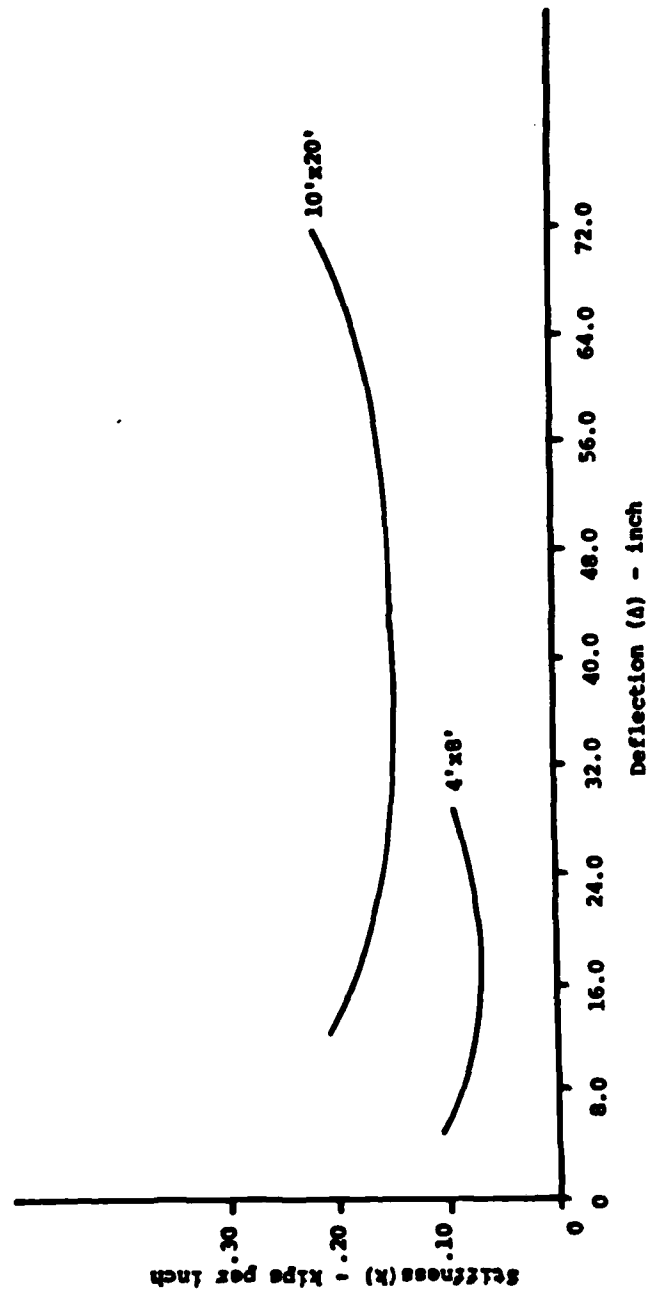
FIG. I-G-1: Stiffness vs. Deflection for Samson Solid Foam Fenders

Samson Cast Fender

32"x6'
32"x4'

Stiffness (k) - kips per inch

Deflection (Δ) - inch
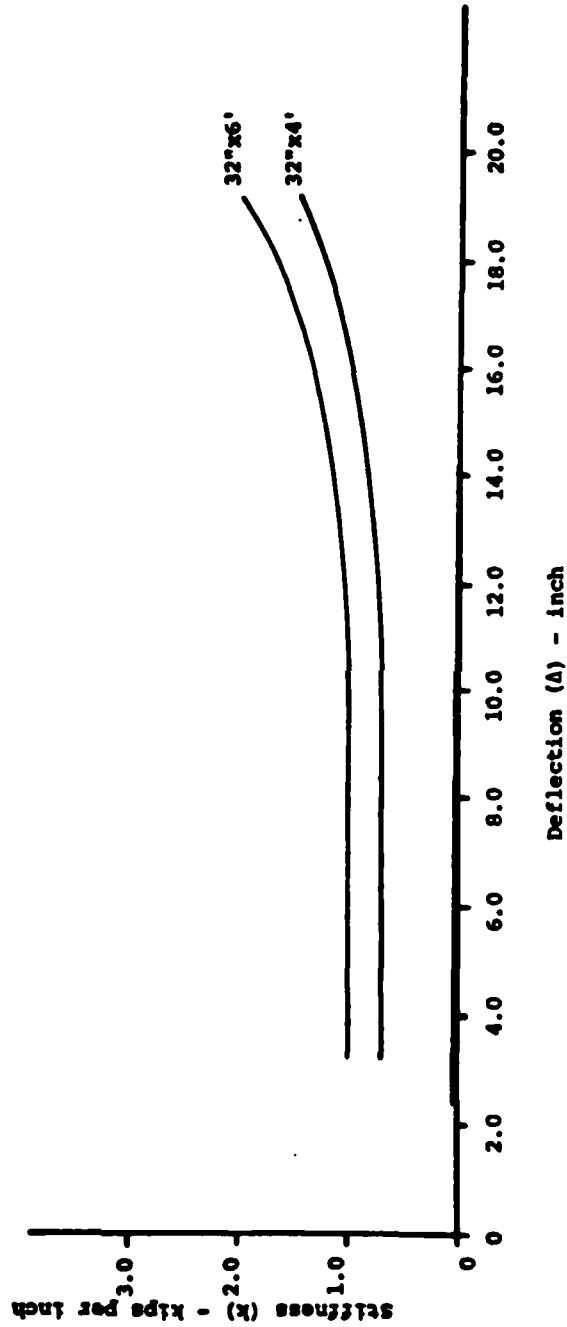
FIG. I-G-2: Stiffness vs. Deflection for Samson Cast Fenders up to 32" x 6'

Samson Cast Fender
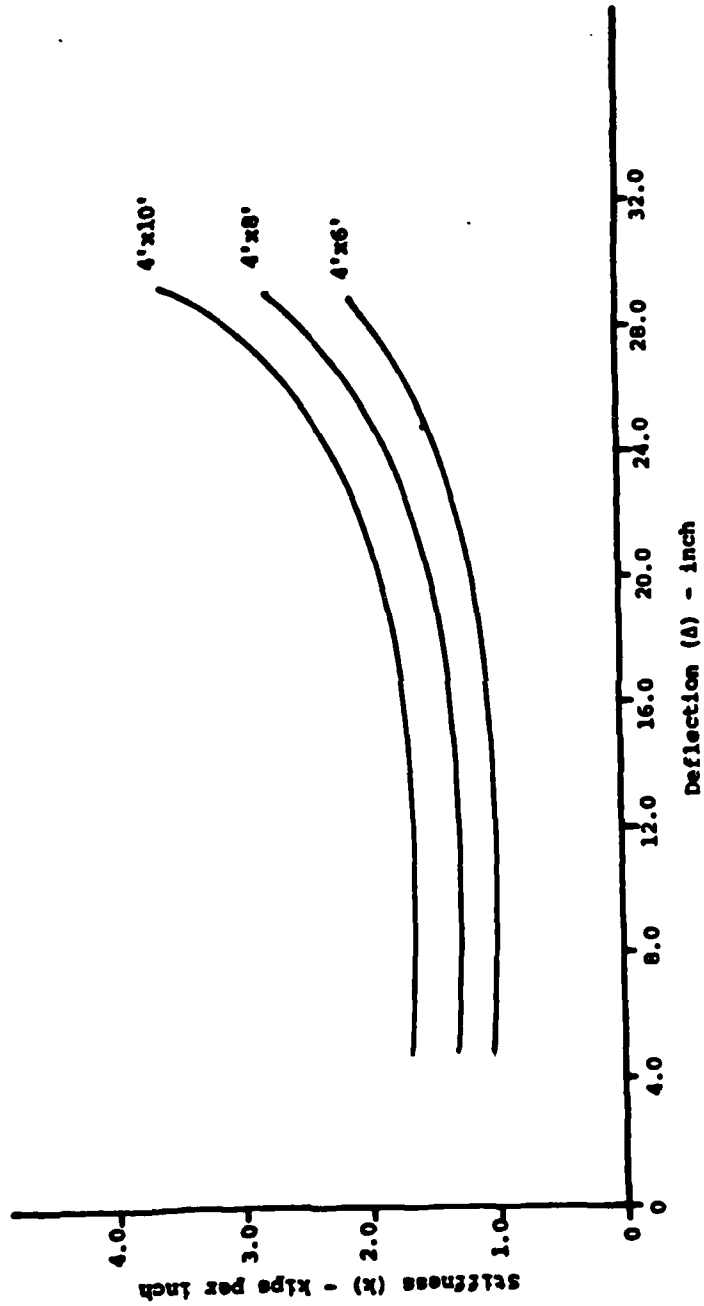
FIG. I-G-3: Stiffness vs. Deflection for Samson Cast Fenders up to 4' x 10'

Samson Sprayed Fender
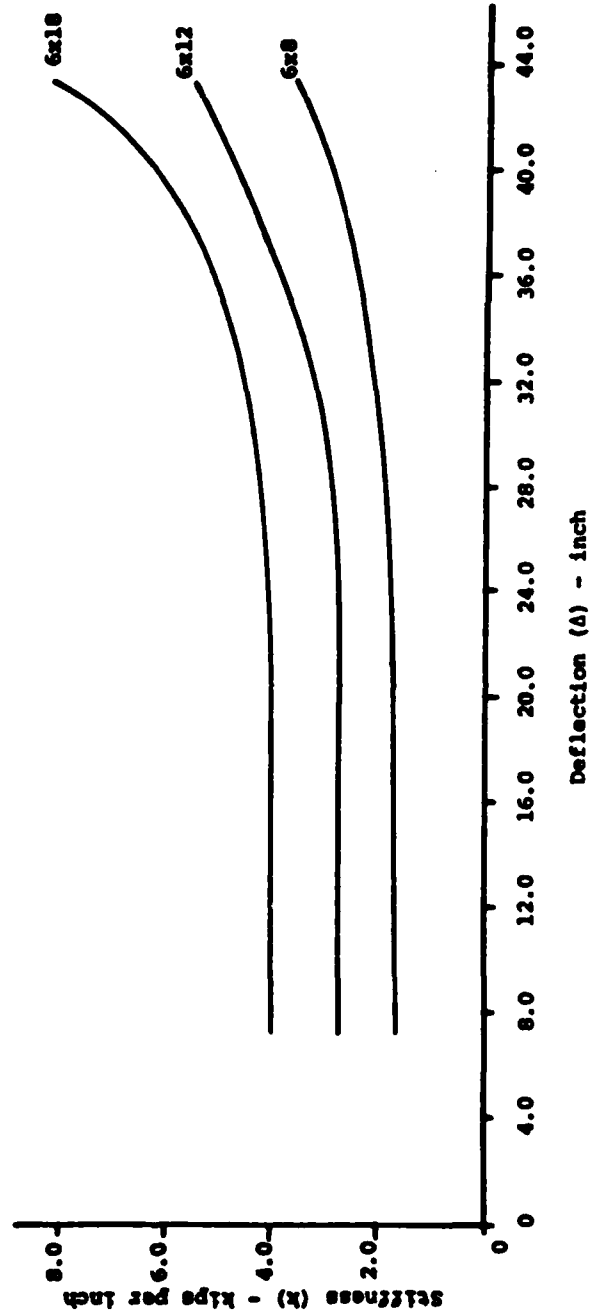
6x18

6x12

6x8

Stiffness (K) - kips per inch

8.0
6.0
4.0
2.0
0

0   4.0   8.0   12.0 16.0 20.0 24.0 28.0 32.0 36.0 40.0 44.0

Deflection (Δ) - inch

FIG. I-C-4: Stiffness vs. Deflection for Samson Sprayed Fender up to 6' x 18'
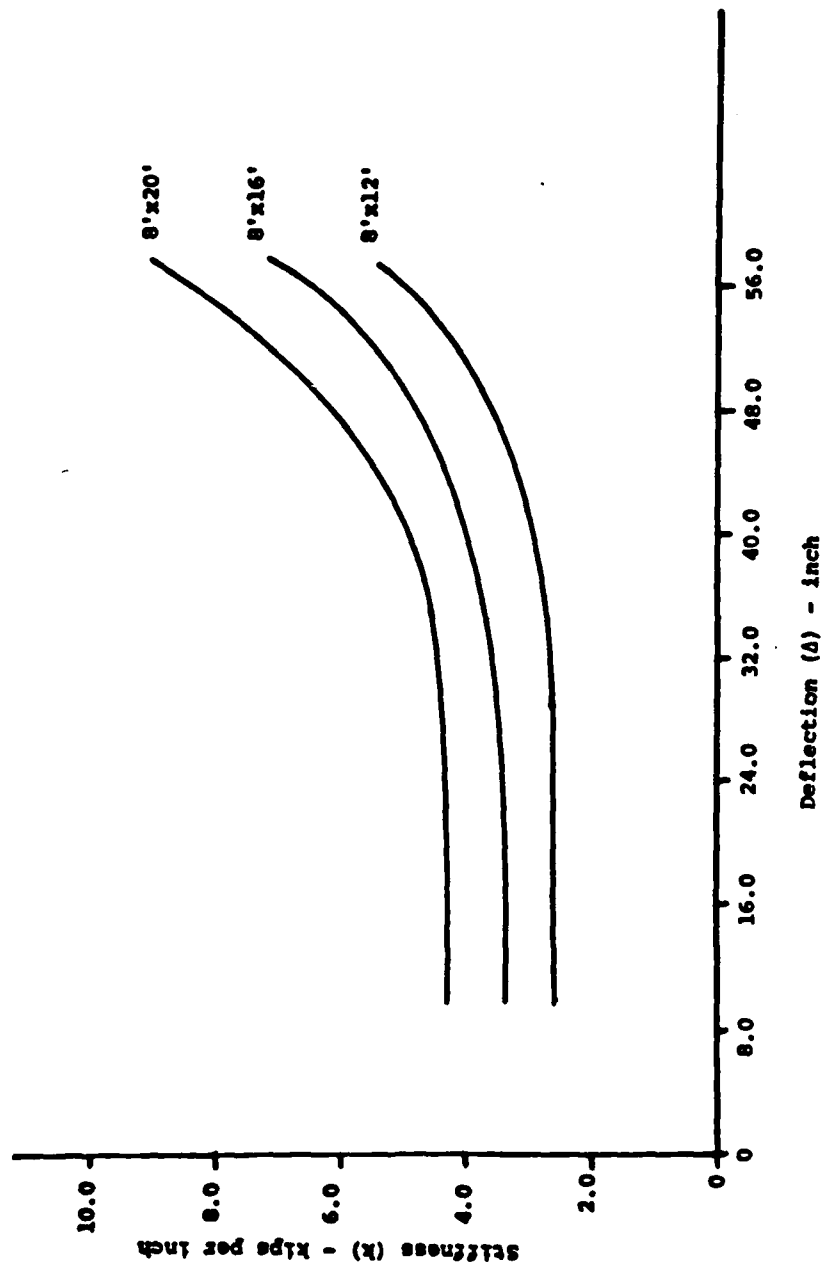
281

Samson Sprayed Fender

8'x20'

8'x16'

8'x12'

Deflection (Δ) - inch

Stiffness (k) - kips per inch

FIG. I-C-5: Stiffness vs. Deflection for Samson Sprayed Fender up to 8' x 20'

282

Samson Sprayed Fender

10x20

10x16

Stiffness (k) - kips per inch

10.0

8.0

6.0

4.0

2.0

0

0   8.0   16.0   24.0   32.0   40.0   48.0   56.0   64.0   72.0

Deflection (Δ) - inch
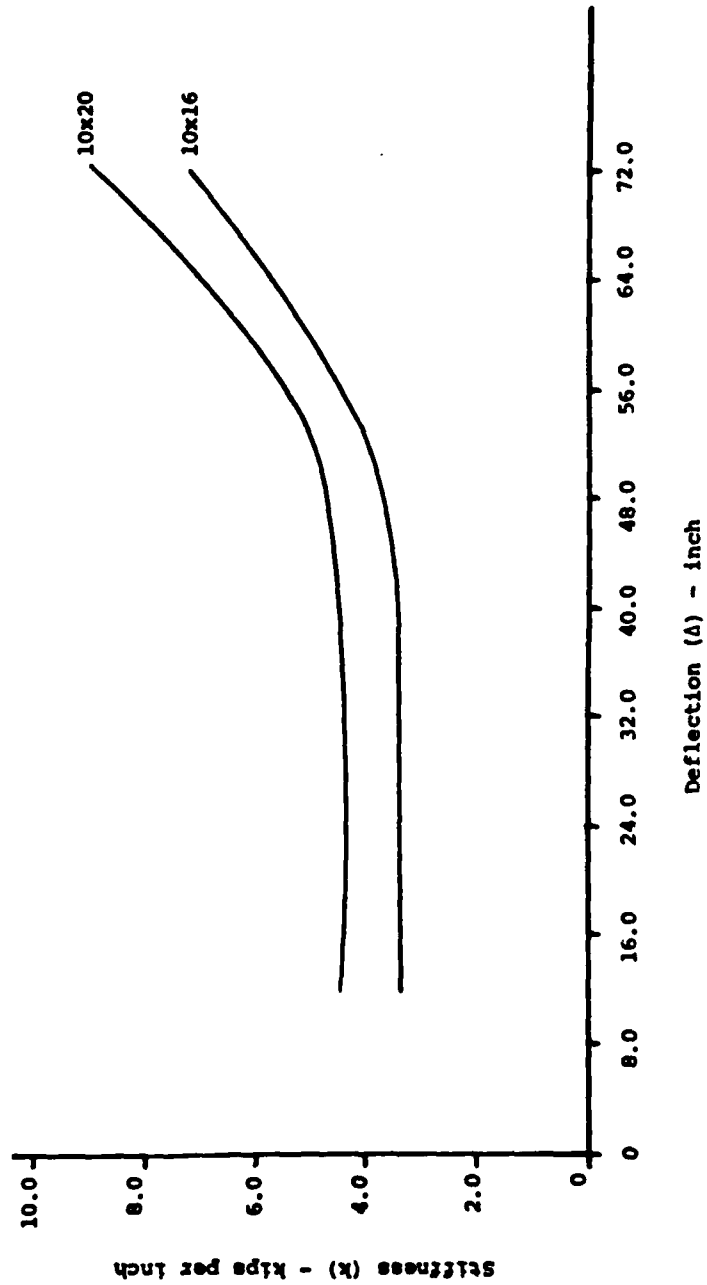
FIG. I-G-6: Stiffness vs. Deflection for Samson Sprayed Fender up to 10'x20'

283

APPENDIX I-B

SEWARD INTERNATIONAL, INC.

Seward Sea-Cushion Fender
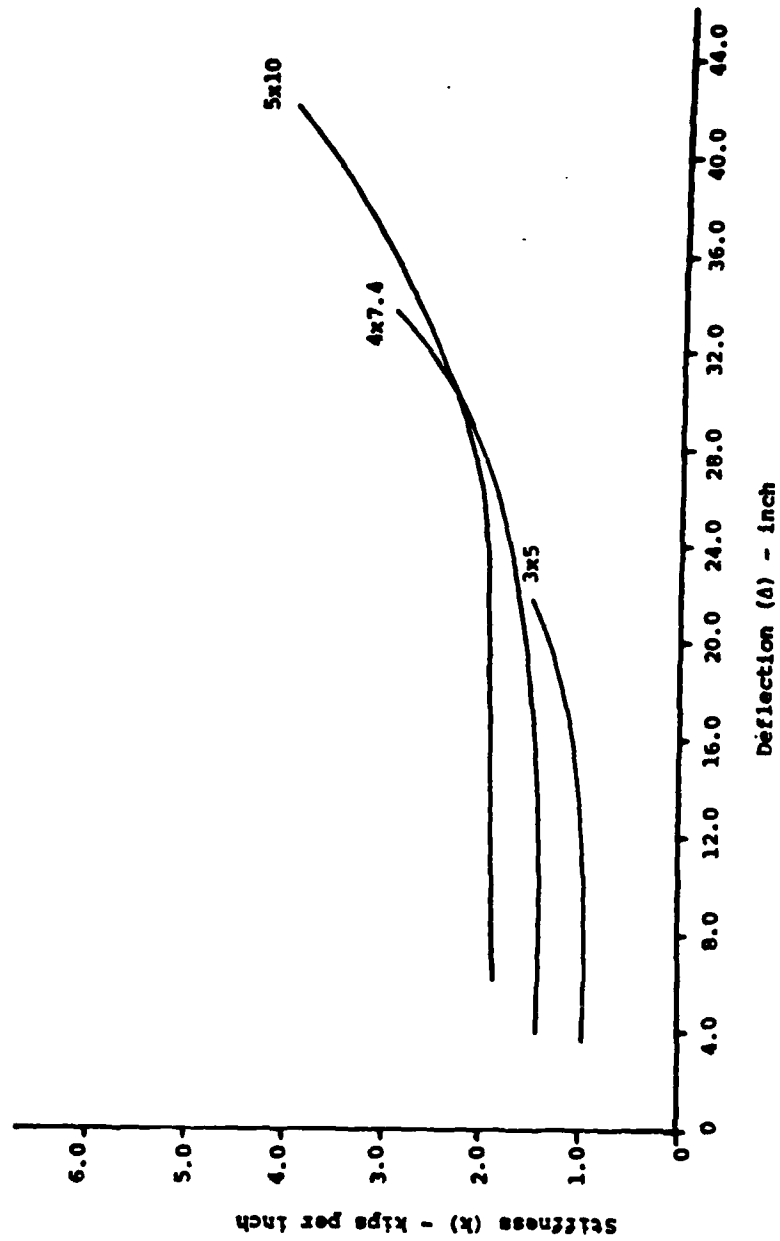
FIG. I-H-1: Stiffness vs. Deflection for Seward Sea Cushion Fender up to 5' x 10'

Deflection (Δ) – inch

Stiffness (k) – kips per inch

5x10

4x7.4

3x5

Seward Sea-Cushion Fender

Stiffness (K) - kips per inch

Deflection (Δ) - inch
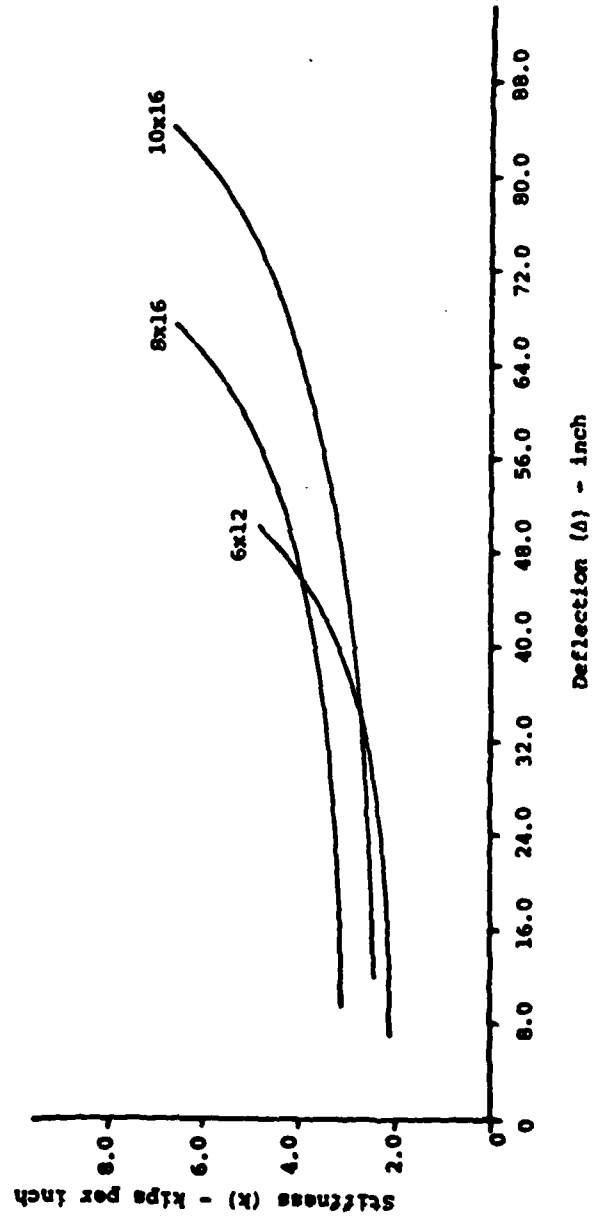
FIG. I-H-2: Stiffness vs. Deflection for Seward Sea Cushion Fender up to 10' x 16'

Seward Sea-Cushion Fender
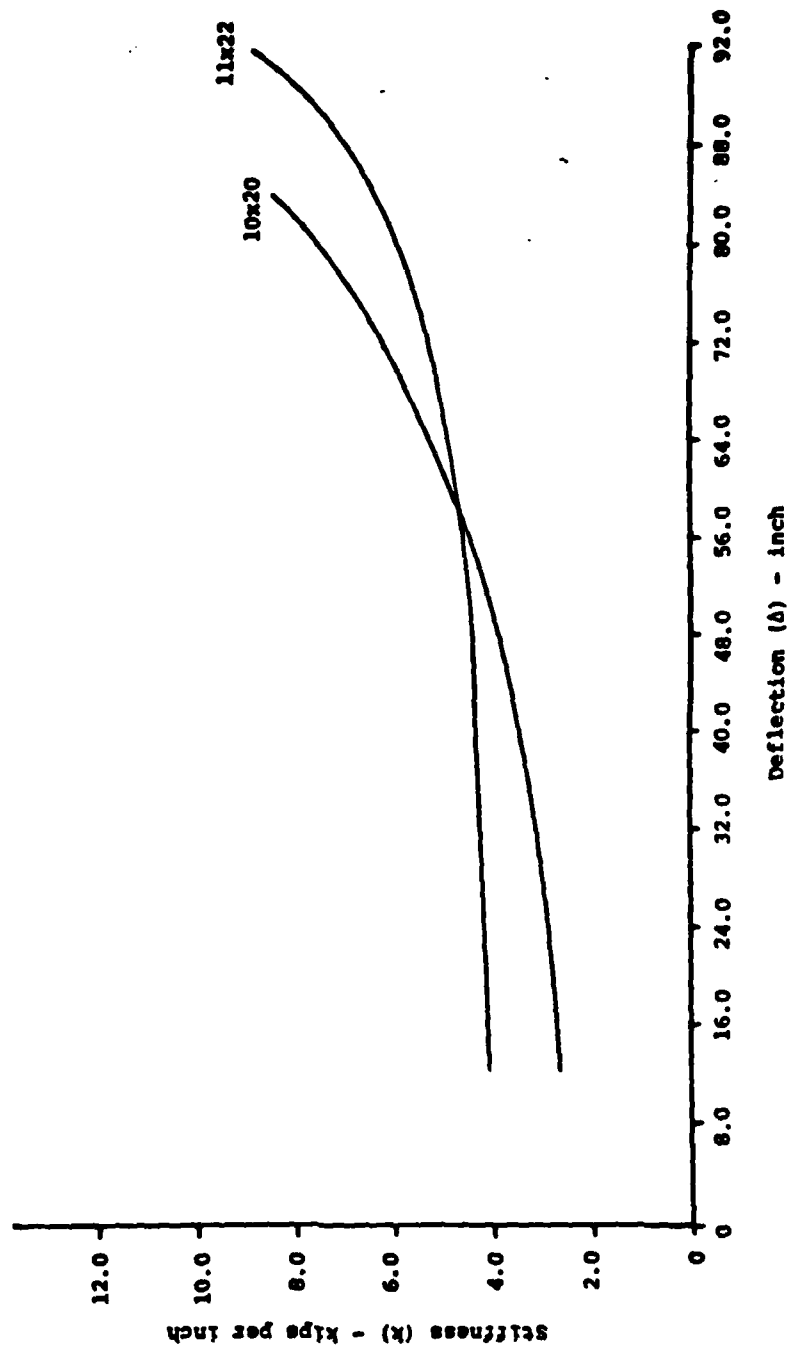
FIG. I-H-3: Stiffness vs. Deflection for Seward Sea Cushion Fender up to 11' x 22'

APPENDIX I-J

UNIROYAL, INC.

Table I-J-1: UNIROYAL ENERGY TABLE

Delta	Δ_{max} = inches					K = kip-in/foot of length					Δ_{max}
	10	20	30	40	50	60	70	80	90	100	
13A	2.4	4.8	11	16	24	34	34	55	65	78	5.7
20A	3.6	9.6	16	24	37	52	67	83	101	116	7.3
23A	4.8	13	28	46	66	90	113	137	162	185	9.5
28A	7.2	19	37	62	91	120	154	187	221	252	11.0
10	2.4	4.8	7.2	11	16	20	25	31	36	41	4.5
15	3.6	6.0	12	18	26	35	46	56	67	79	5.9
20	4.8	11	20	31	44	60	76	92	108	125	7.8
25	7.2	18	32	50	72	97	120	146	172	199	9.9

Cylindrical

	10	20	30	40	50	60	70	80	90	100	Δ_{max}
5			6.0	9.6	11	12	18	30	48	72	4.3
7			8.4	12	13	14	16	30	48	96	5.3
8			9.6	11	12	14	18	36	60	106	6.0
10		7.2	11	12	16	22	24	48	84	168	7.3
12		8.4	12	14	22	25	36	72	102	228	9.0
15	4.8	12	14	22	28	36	48	84	156	336	11.1
18	6.0	12	18	24	36	50	66	108	180	414	13.3
21	6.0	12	22	32	48	62	84	144	228	492	15.3
24	9.6	16	28	42	60	84	128	252	312	612	18.0
28		12	16	30	46	76	104	134	168	228	17.0
32		12	24	36	60	90	132	168	210	288	19.0
36		12	24	54	76	112	150	204	254	348	21.0
48		16	46	84	136	196	264	344	426	576	27.5
60	12	30	68	120	196	277	376	496	630	828	33.0

Rectangular

	10	20	30	40	50	60	70	80	90	100	Δ_{max}
3.5x4.5x1	3.0	8.4	12	18	24	31	38	49	61	96	2.3
5x6x2.5	3.0	6.0	11	14	23	30	44	58	78	100	3.3
5x6x2.5	3.6	7.2	12	17	24	30	37	48	80	122	3.6
6x6.5x2.5	4.8	9.6	13	22	28	38	49	64	102	198	4.1
8x10x3	4.8	11	17	28	38	52	70	92	131	216	5.0
8x8x3	4.8	12	22	26	36	52	73	103	146	240	5.5
10x12x4	6.0	16	24	32	50	72	98	142	209	336	6.75
12x12x5	7.2	20	30	36	62	188	125	181	250	384	8.0
14x14x6	11	23	35	50	72	102	140	197	264	384	9.0

Cyl. End Ld.	10	20	30	40	50	60	70	80	90	100	Δ_{max}
								Σ = Kip-in./foot of length			
10	12	18	28	36	46	64	84	90	126	172	7.8
12	18	28	36	46	64	90	126	180	216	270	9.8
15	36	54	100	144	198	244	298	360	450	540	12.8
18	46	90	144	198	270	342	414	504	604	784	14.5
21	82	154	234	342	450	558	702	850	1026	1260	17.8
24	100	190	316	456	612	792	980	1188	1458	1800	19.7

Wing Type

	10	20	30	40	50	60	70	80	90	100	Δ_{max}
6x2				3.0	7.2	17	26	37	58	84	3.7
6x3					6.0	13	24	38	59	95	4.1
8x4				4.8	14	30	52	84	120	178	5.6
10x4				9.6	23	38	66	73	148	216	6.8
12x5			6.0	16	34	59	89	137	216	562	8.3

Table I-J-2: UNIROYAL CURVE COEFFICIENTS

Wing Type $K = a + b\Delta + c\Delta^2$ or K = kips/inch/foot of length
              $= a' + b'\Delta$ Δ = inch

	a	b	c	boundary lower	upper	a'	b'	boundary lower	upper
6x2	14.03	-13.98	4.95	1.0	3.5	---	---	---	---
6x3	12.90	-14.42	4.52	1.0	4.0	---	---	---	---
8x4	3.60	- 4.21	1.61	1.0	5.5	---	---	---	---
10x4	3.49	- 3.56	1.07	3.0	6.75	- .80	+ 1.8	1.0	3.0
12x5	2.50	- 2.07	.561	3.0	8.25	0	+ 1.00	1.0	3.0

Cylindrical $K = a + b\Delta$ or
                $= a' + b'\Delta + c'\Delta^2$

	a	b	boundary lower	upper	a'	b'	c'	boundary lower	upper
5"	1.82	- .018	1.0	2.2	9.34	- 12.90	4.19	2.2	4.1
7"	1.82	- .018	1.0	3.3	19.18	- 15.56	3.11	3.3	5.25
8"	1.82	- .018	1.0	3.8	6.46	- 9.28	2.07	3.8	6.00
10"	1.82	- .018	1.0	5.0	80.15	- 33.37	3.53	5.0	7.40
12"	1.82	- .018	1.0	5.9	25.10	- 10.32	1.08	5.9	9.00
15"	1.82	- .018	1.0	8.5	133.20	- 33.23	2.09	8.5	11.25
18"	1.82	- .018	1.0	9.0	60.74	- 13.32	.750	9.0	13.40
21"	1.82	- .018	1.0	10.5	55.92	- 10.41	.500	10.5	15.75
24"	1.82	- .018	1.0	12.0	47.00	- 7.83	.336	12.0	17.90
28"	1.24	+ .004	2.0	13.0	19.21	- 2.70	.101	13.0	16.50
32"	1.24	+ .004	2.0	13.5	33.95	- 4.15	.132	13.5	18.50
36"	1.24	+ .004	2.0	17.0	52.63	- 5.71	.158	17.0	21.30
48"	1.24	+ .004	2.0	23.5	69.36	- 5.07	.119	23.5	28.0
60"	1.24	+ .004	2.0	27.0	52.13	- 3.49	.060	27.0	35.50

Rectangular $K = a + b\Delta$ or
                $= a' + b'\Delta + c'\Delta^2$

	a	b	boundary lower	upper	a'	b'	c'	boundary lower	upper
3.5x4.5x1	23.0	- .50	.50	1.0	38.72	- 46.08	23.36	1.0	2.25
5x6x2.5	23.0	- .50	.50	1.50	176.56	-145.92	32.32	1.5	3.25
5x6x2.5	23.0	- .50	.50	2.0	33.03	- 22.57	5.77	2.0	3.75
6x6.5x2.5	23.0	- .50	.50	2.0	44.57	- 28.05	5.63	2.0	4.00
8x10x3	23.0	- .50	.50	2.0	69.50	- 38.03	6.267	2.0	5.0
8x8x3	10.84	- 1.67	.5	2.0	40.60	- 21.70	3.700	2.0	5.0
10x12x4	10.84	- 1.67	.5	2.5	17.27	- 7.40	1.35	2.5	6.5
12x12x5	10.84	- 1.67	.5	3.0	17.88	- 6.70	.988	3.0	8.0
14x14x6	10.84	- 1.67	.5	3.5	15.11	- 4.64	.632	3.5	8.75

Delta and Delta A   K = a + bΔ

	a	b	boundary lower	upper
13A	7.00	- .636	0.0	6.0
20A	7.28	- .600	0.0	7.5
23A	7.75	- .581	0.0	8.5
28A	8.00	- .528	0.0	10.0
10	7.70	-1.20	1.0	4.0
15	6.65	- .580	0.0	5.5
20	7.20	- .579	0.0	7.5
25	8.09	- .588	0.0	9.0

Cylindrical End-Loaded   K = Constant or
                                  = a + bΔ

	a	b	boundary lower	upper
10x5	3.85	- .075	2.0	8.0
12x6	4.5	---	2.0	10.0
15x75	6.0	---	2.0	13.0
18x9	7.0	---	4.0	14.0
21x10.5	8.55	- .025	2.0	18.0
24x12	9.3	---	4.0	20.0
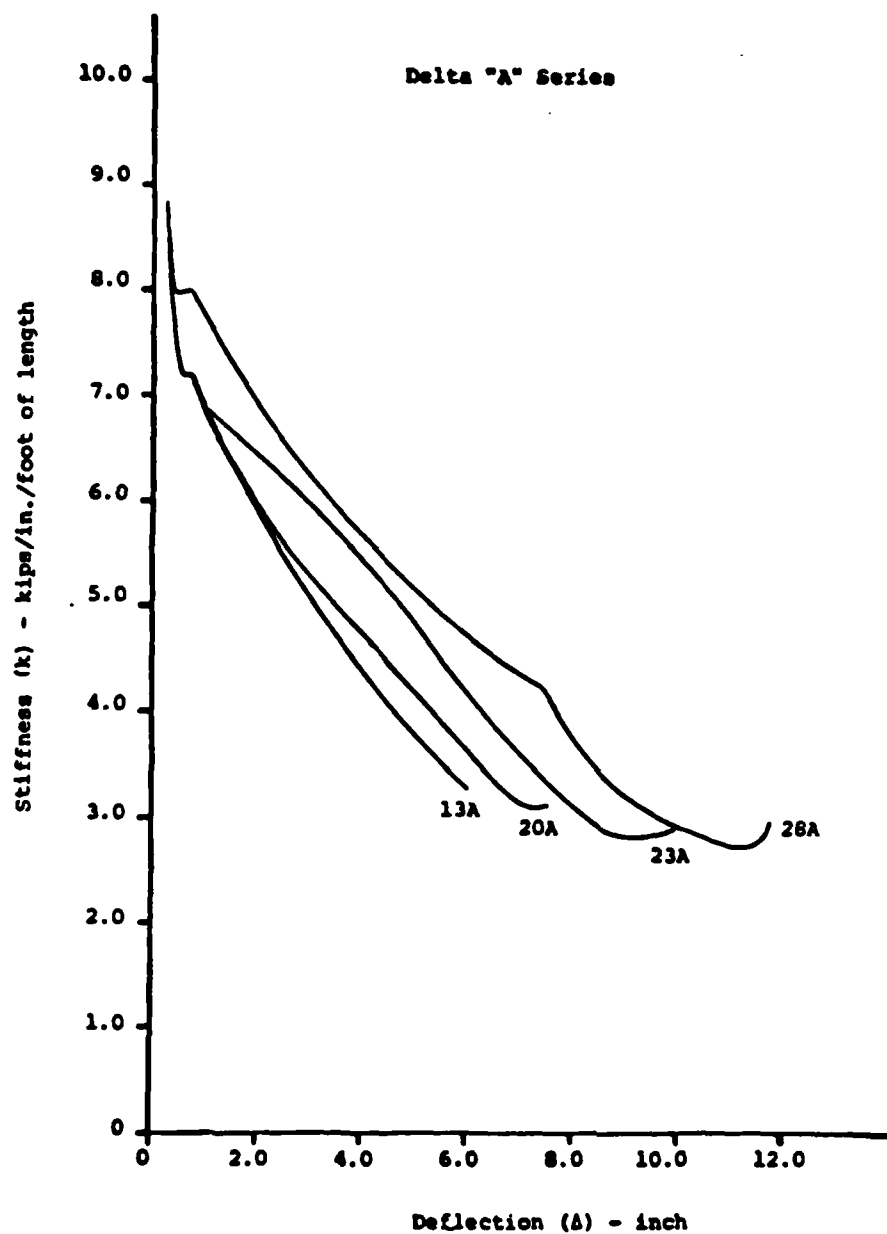
FIG. I-J-1: Stiffness vs. Deflection for Uniroyal Delta A Series

294
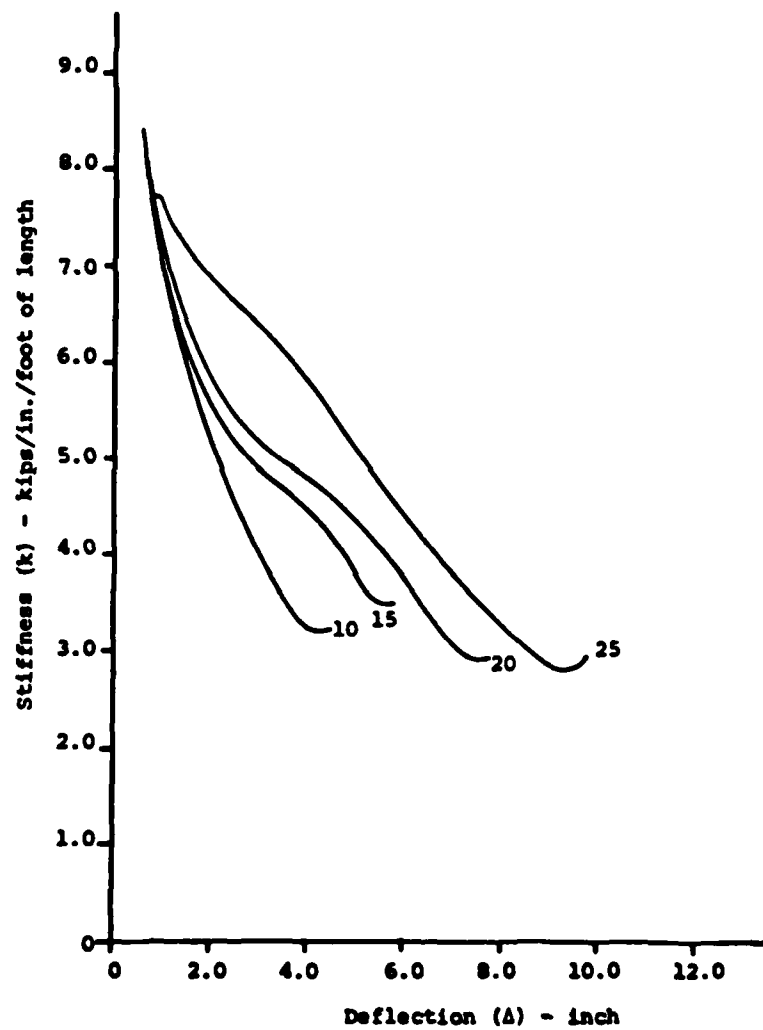
Delta Series

FIG. I-J-2: Stiffness vs. Deflection for Uniroyal Delta Series

Cylindrical Hanging Fenders
5" to 24" O.D.
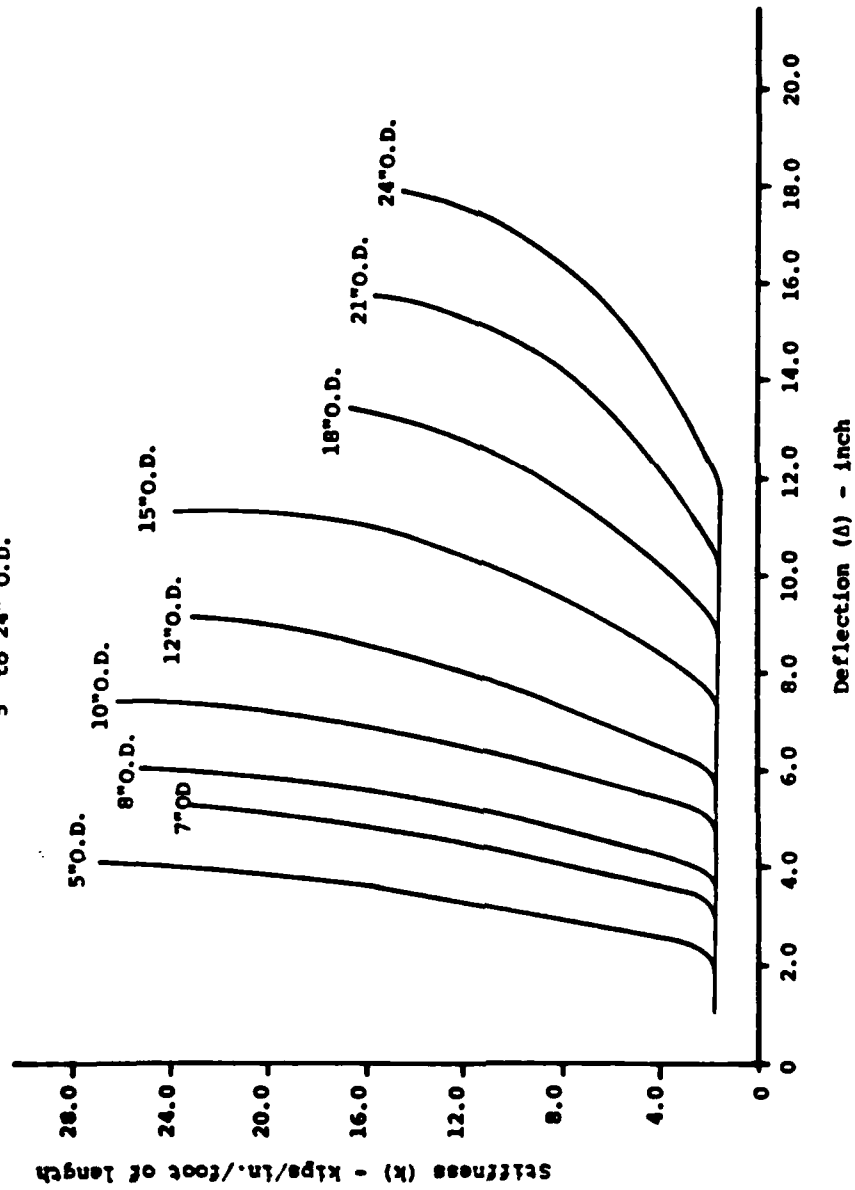
FIG. I-J-3: Stiffness vs. Deflection for Uniroyal Cylindrical Fenders up to 24" O.D.

Cylindrical Hanging Fenders
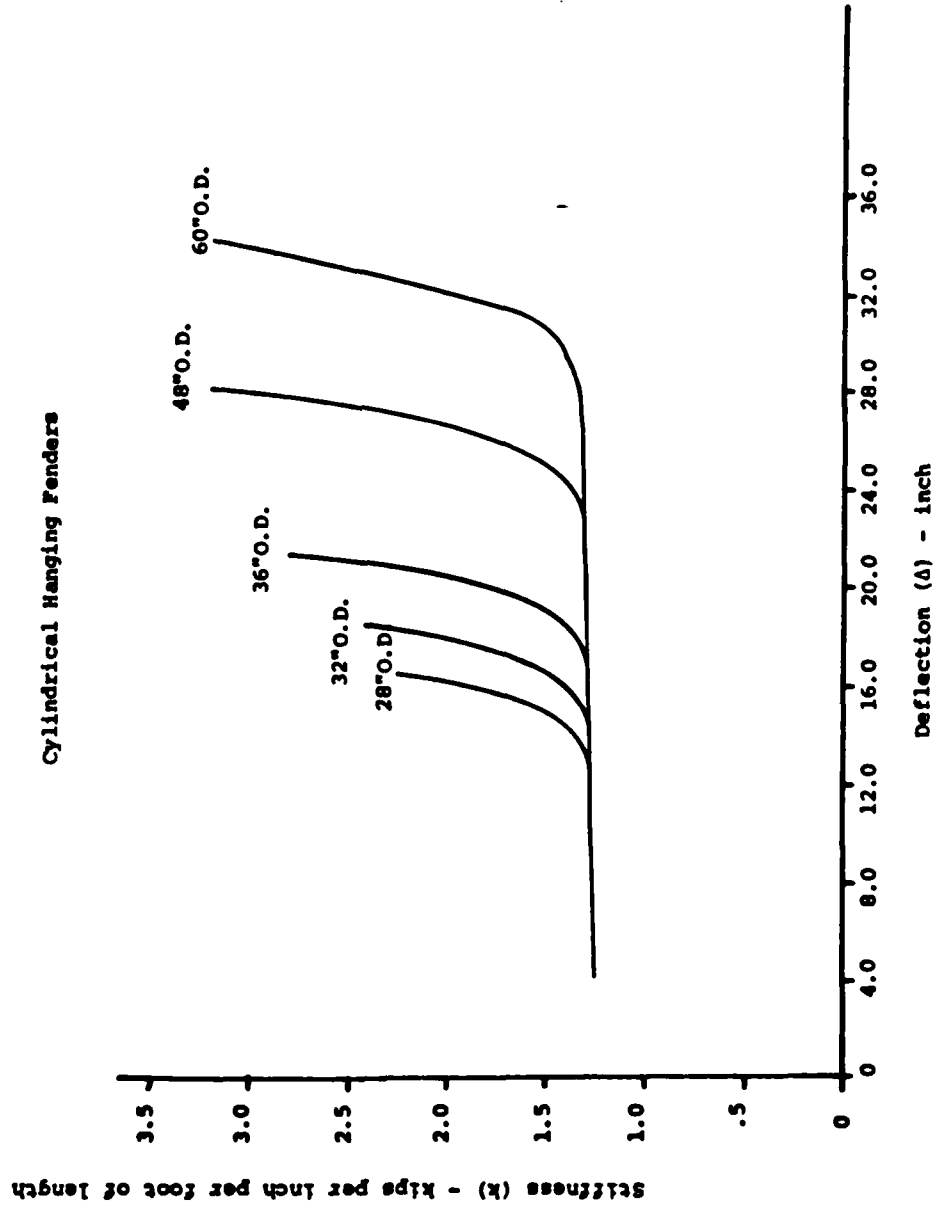
FIG. I-J-4: Stiffness vs. Deflection for Uniroyal Cylindrical Hanging Fenders up to 60" O.D.

Rectangular Fenders
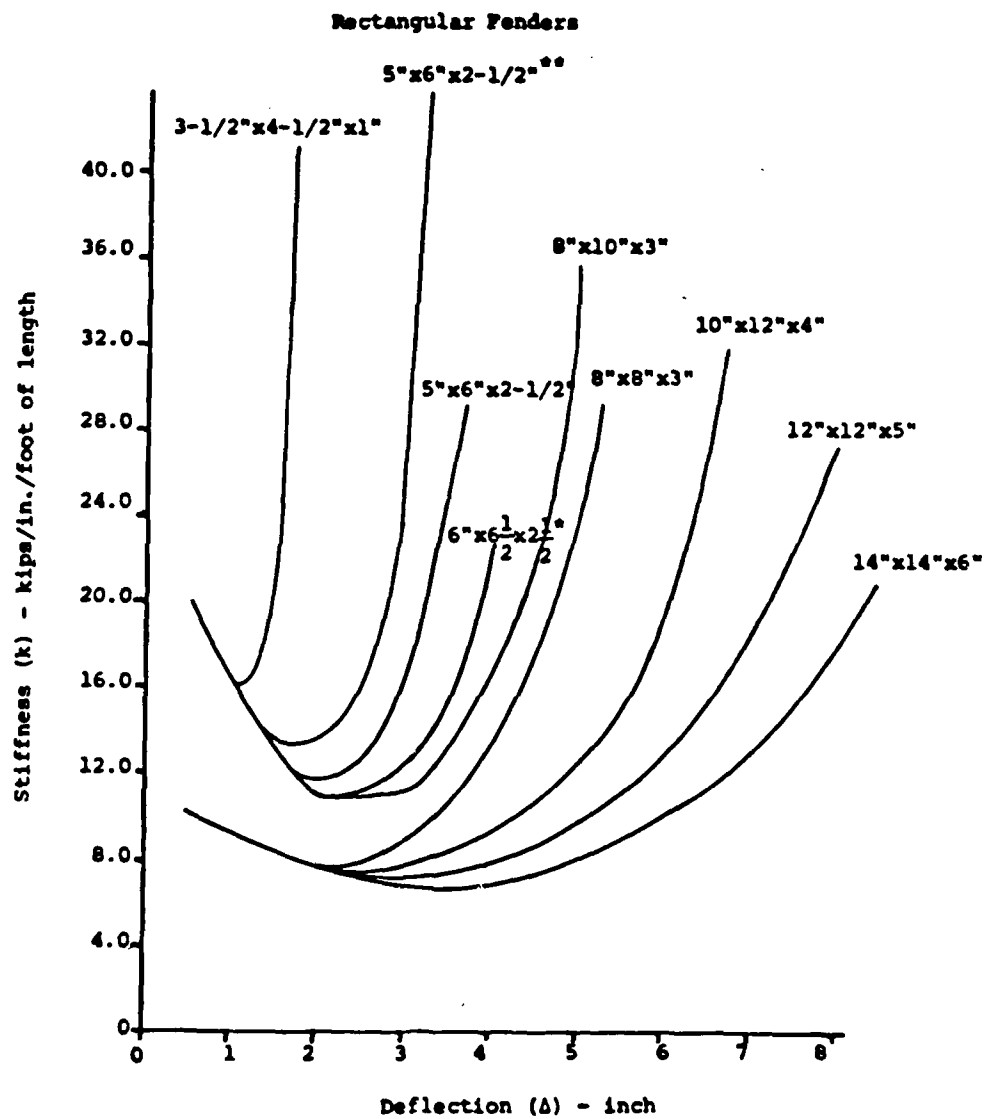
FIG. I-J-5: Stiffness vs. Deflection for Uniroyal Rectangular Fenders
Axially Loaded

Rectangular Fenders - Shear Load
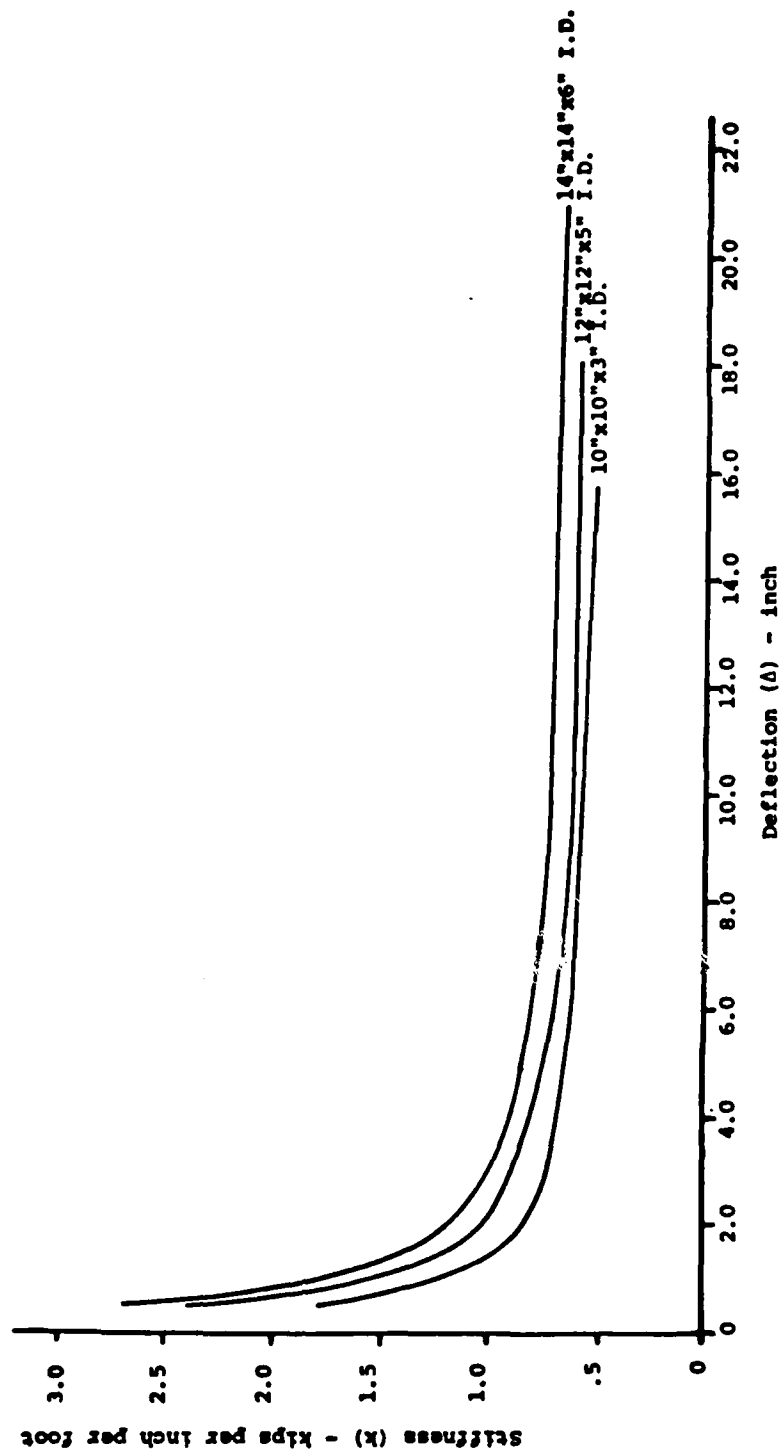
FIG. I-J-5: Stiffness vs. Deflection for Uniroyal Rectangular Fenders in Shear

Cylindrical Fenders   End loaded

Stiffness (K) - klpa/in./foot of length

Deflection (Δ) - inch

24"O.D.x12"I.D.

21"O.D.x10-1/2"I.D.

18"O.D.x9"I.D.

15"O.D.x7-1/2"I.D.

12"O.D.x 6"I.D.

10"O.D.x5"I.D.
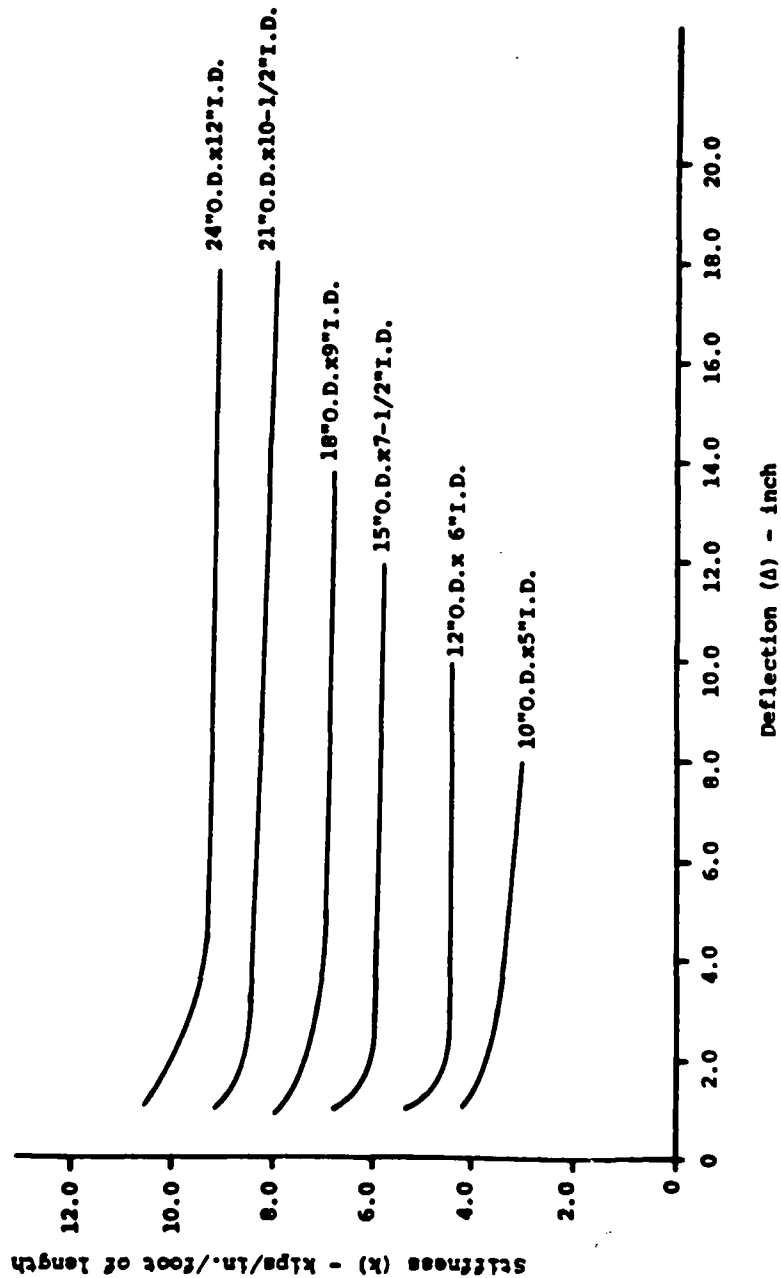
FIG. I-J-7: Stiffness vs. Deflection for Uniroyal Cylindrical Fenders End Loaded

Wing-type Fenders
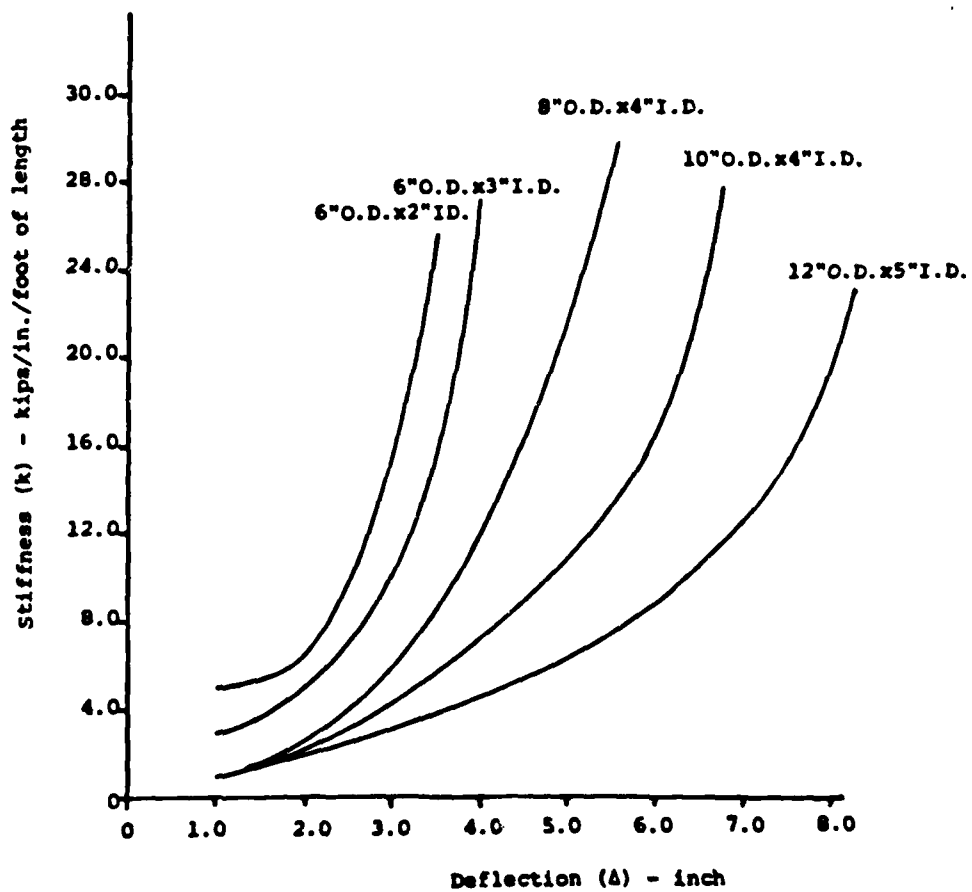
FIG. I-J-8: Stiffness vs. Deflection for Uniroyal Wing-type Fenders

APPENDIX I-K

YOKOHAMA RUBBER COMPANY, LTD.

Table I-K-1: YOKOHAMA ENERGY TABLE

Pneumatics   E = Kip-in.

	10	20	30	40	50	60	70	80	90	100	Δ_{max}
700x1500		6.0	15	39	72	132					27.6
1000x1500		11	25	60	120	240					39.4
1000x2000	3	15	39	85	174	350					39.4
1350x2500	12	30	84	195	390	780					53.1
1500x3000	18	54	120	290	610	1150					59.1
1700x3000	20	72	180	370	750	1440					66.9
2000x3500	24	105	240	550	1170	2315					78.7
2500x5500		360	900	1800	3900	6900					98.4
3300x6500		720	2040	4560	8940	16200					129.9
4500x9000		2100	5400	12000	23750	42300					177.2

Air Block   E = Kip-in.

	10	20	30	40	50	60	70	80	90	100	Δ_{max}
300x 400		2.2	5.2	9.6	17	26	41				
450x 600		8.7	17	35	52	96	143				
600x 800		17	39	78	130	210	320				
750x1000		43	87	156	260	420	650				
900x1200		80	150	280	435	715	1112				
1200x1600		175	350	650	1043	1650	2700				
1500x2000		300	735	1260	2085	3475	5213				

Table I-K-2: YOKOHAMA CURVE COEFFICIENTS

Pneumatics: $K = a + b\Delta + c\Delta^2$

K = Kips per inch
Δ = inch

	a	b	c	boundary lower	upper
700x1500	.397	-.032	.0076	1.38	15.16
1000x1500	.346	-.026	.0050	1.97	23.67
1000x2000	1.317	-.150	.0072	2.00	23.62
1350x2500	.552	-.041	.0037	3.94	31.50
1500x3000	.748	-.040	.0034	7.87	35.43
1700x3000	.633	-.039	.0030	3.94	38.00
2000x3500	.967	-.047	.0023	4.00	47.20
2500x5500	1.414	-.017	.0019	7.87	55.12
3300x6500	2.170	-.032	.0016	15.75	78.74
4500x9000	2.734	-.018	.0011	19.69	98.43

Air Blocks: $K = a + b\Delta + c\Delta^2$

300x 400	.820	-.099	.028	1.0	7.90
450x 600	1.474	-.163	.023	1.95	11.80
600x 800	1.793	-.140	.017	2.30	16.55
750x1000	4.493	-.413	.020	3.95	19.70
900x1200	2.837	-.099	.0086	4.00	23.60
1500x2000	5.894	-.200	.0066	8.00	39.40
1200x1600	5.608	-.290	.0103	4.0	31.50

Yokohama Pneumatic Fender
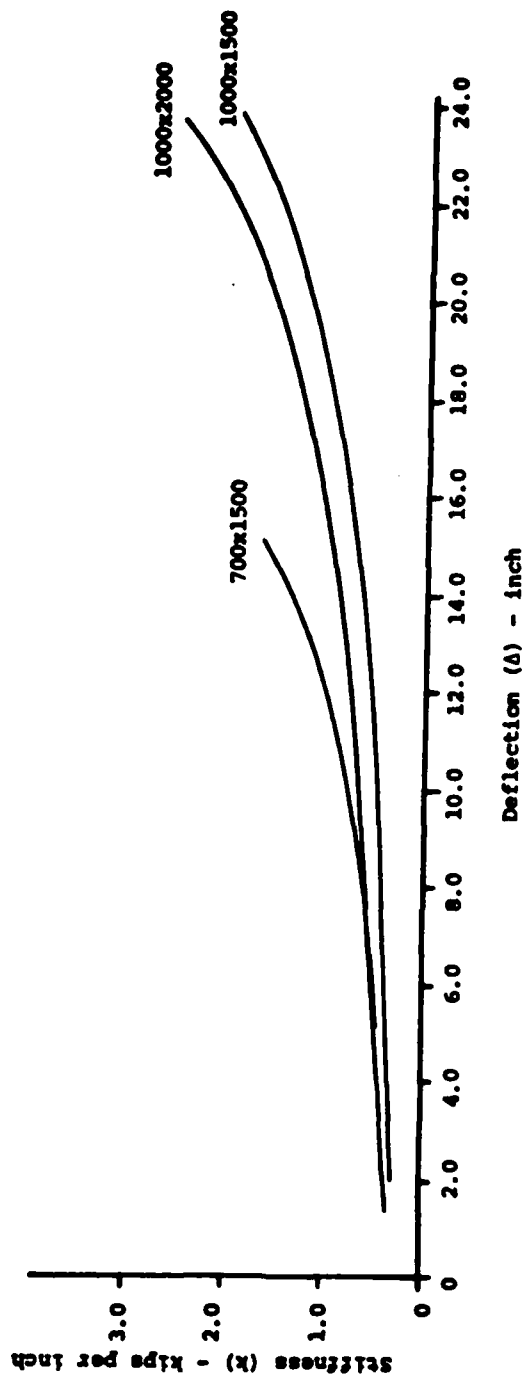
FIG. I-K-1: Stiffness vs. Deflection for Yokohama Pneumatic Fender up to 1000 x 2000

305

Yokohama Pneumatic Fenders
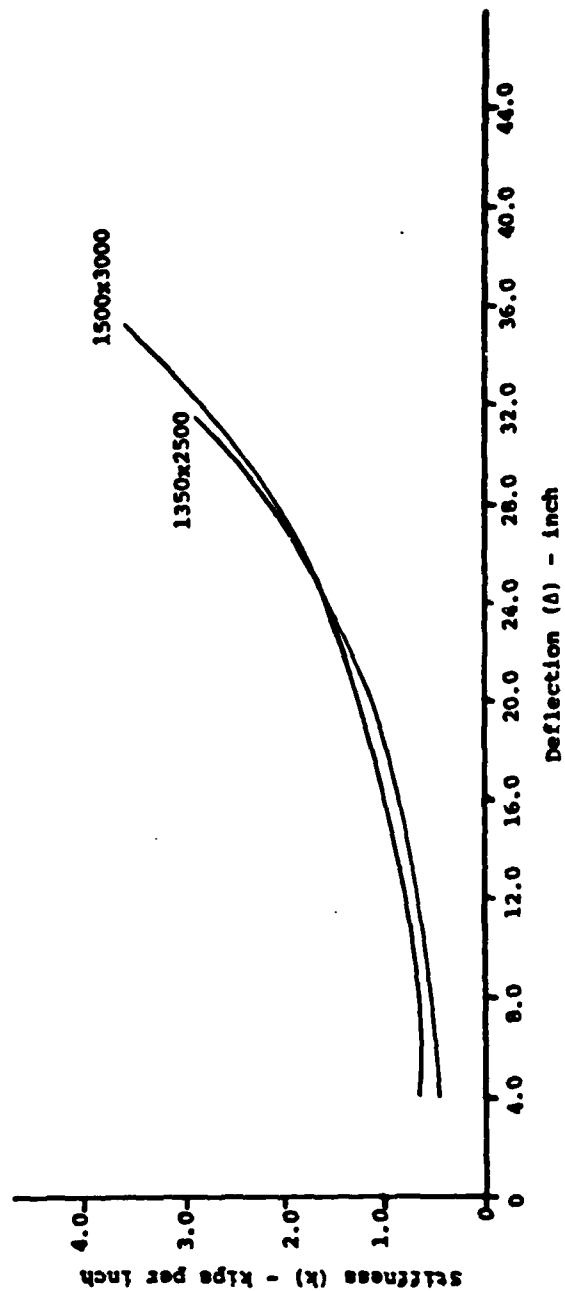
FIG. I-K-2: Stiffness vs. Deflection for Yokohama Pneumatic Fenders up to 1500 x 3000

Yokohama Pneumatic Fender
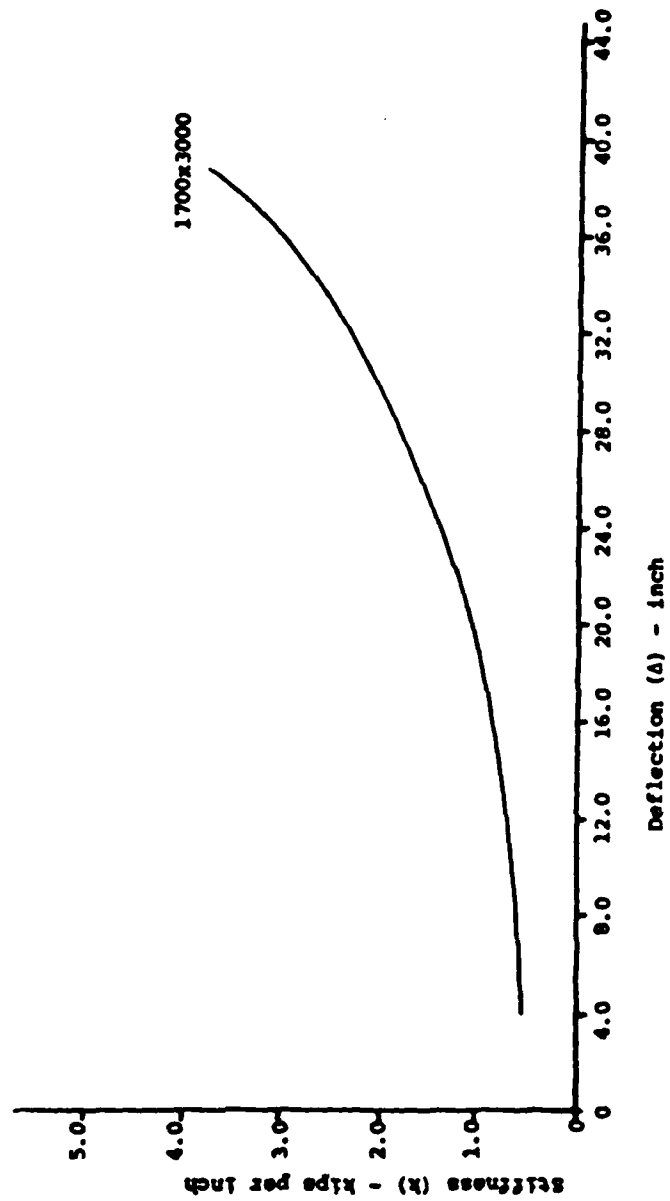
FIG. I-K-3: Stiffness vs. Deflection for Yokohama Pneumatic Fender 1700 x 3000

Yokohama Pneumatic Fender

2000x3500

Deflection (Δ) – inch

Stiffness (k) – kips per inch
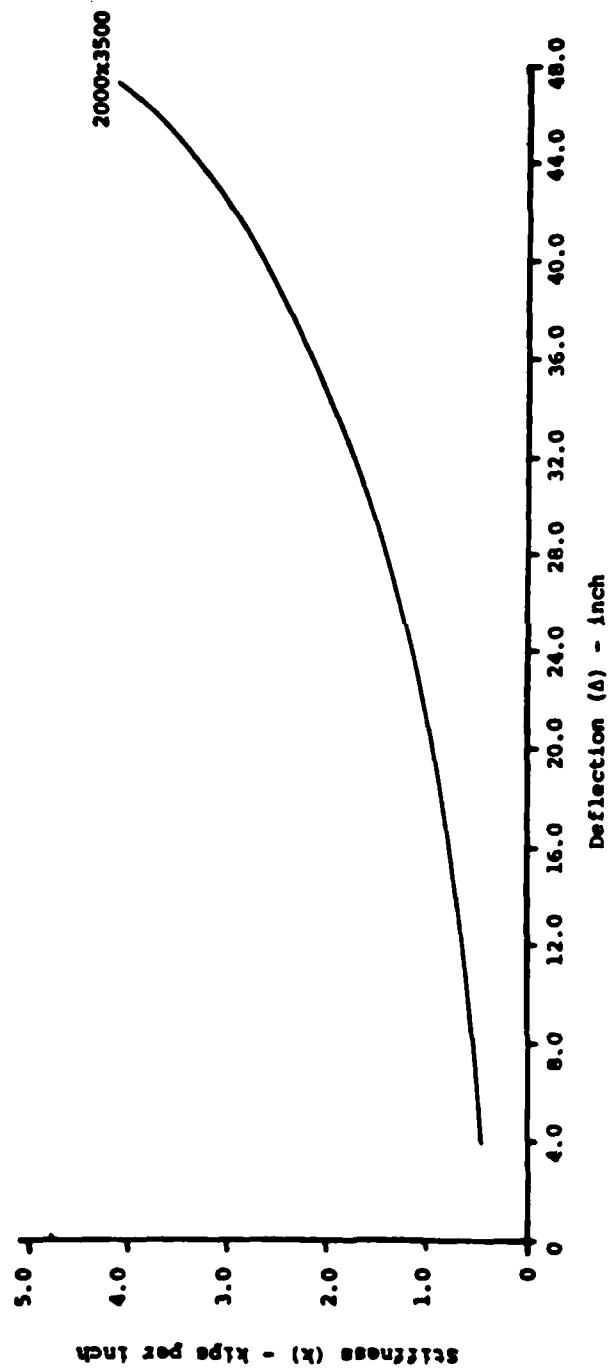
FIG. I-K-4: Stiffness vs. Deflection for Yokohama Pneumatic Fender 2000 x 3500

308

Yokohama Pneumatic Fender
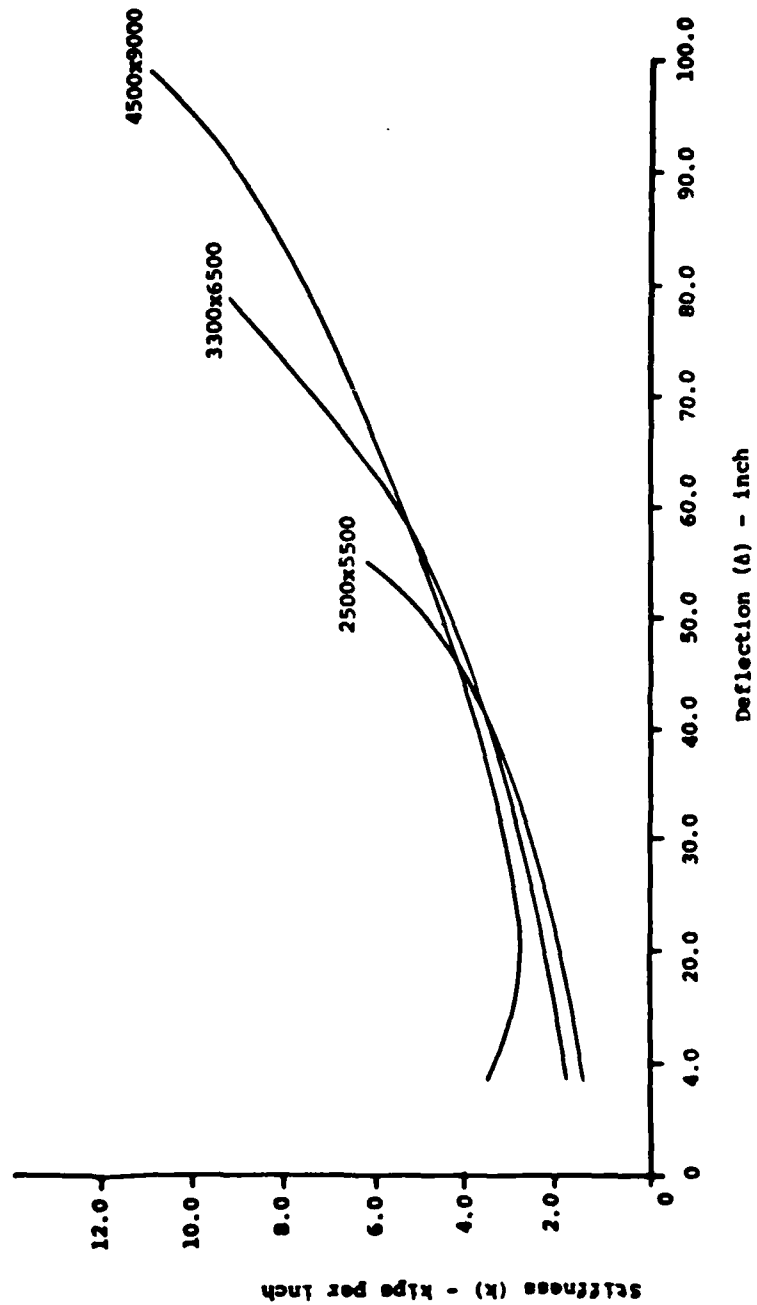
FIG. I-K-5: Stiffness vs. Deflection for Yokonama Pneumatic Fender up to 4500 x 9000

Yokohama Air Block Fenders

450x600

300x400

Deflection (Δ) - inch

Stiffness (K) - kips per inch

3.0 2.0 1.0

0   2.0   4.0   6.0   8.0   10.0   12.0
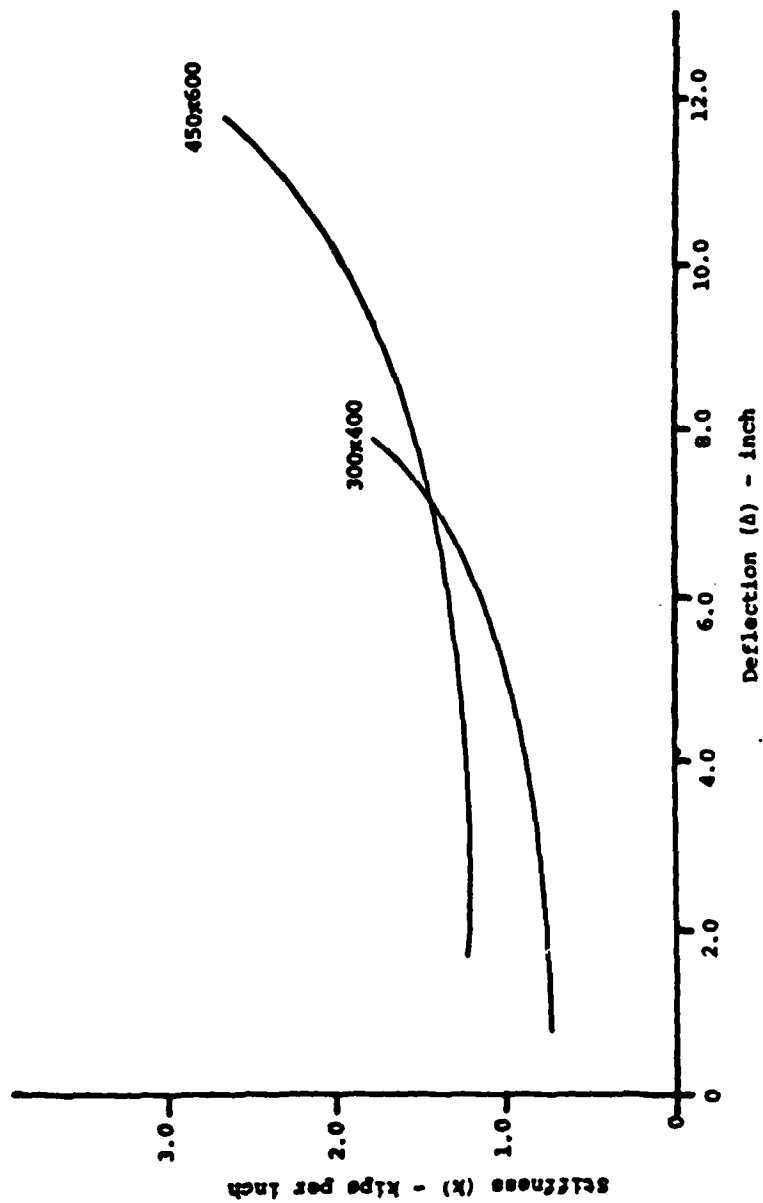
FIG. I-K-6: Stiffness vs. Deflection for Yokohama Air Blocks up to 450 x 600

Yokohama Air Block Fenders
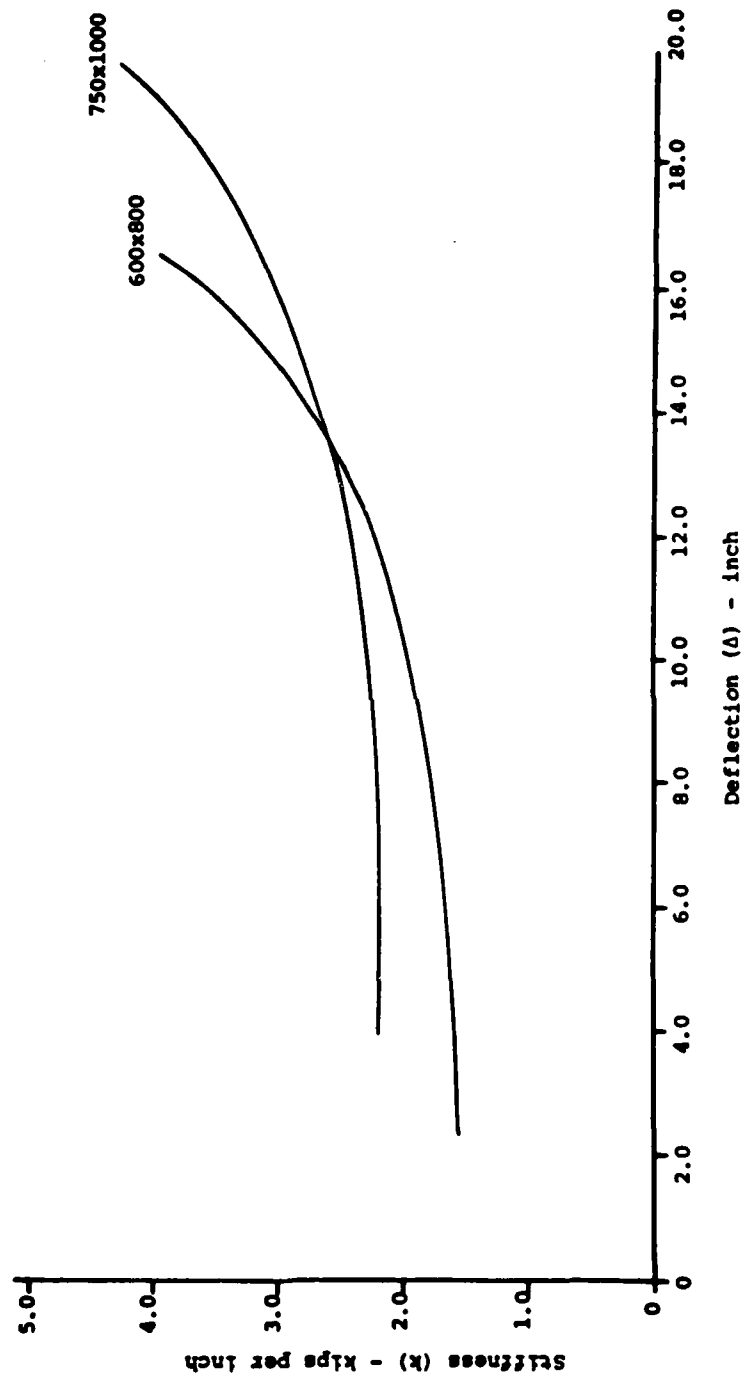
FIG. I-K-7: Stiffness vs. Deflection for Yokohama Air Blocks up to 750 x 1000

Yokohama Air Block Fenders
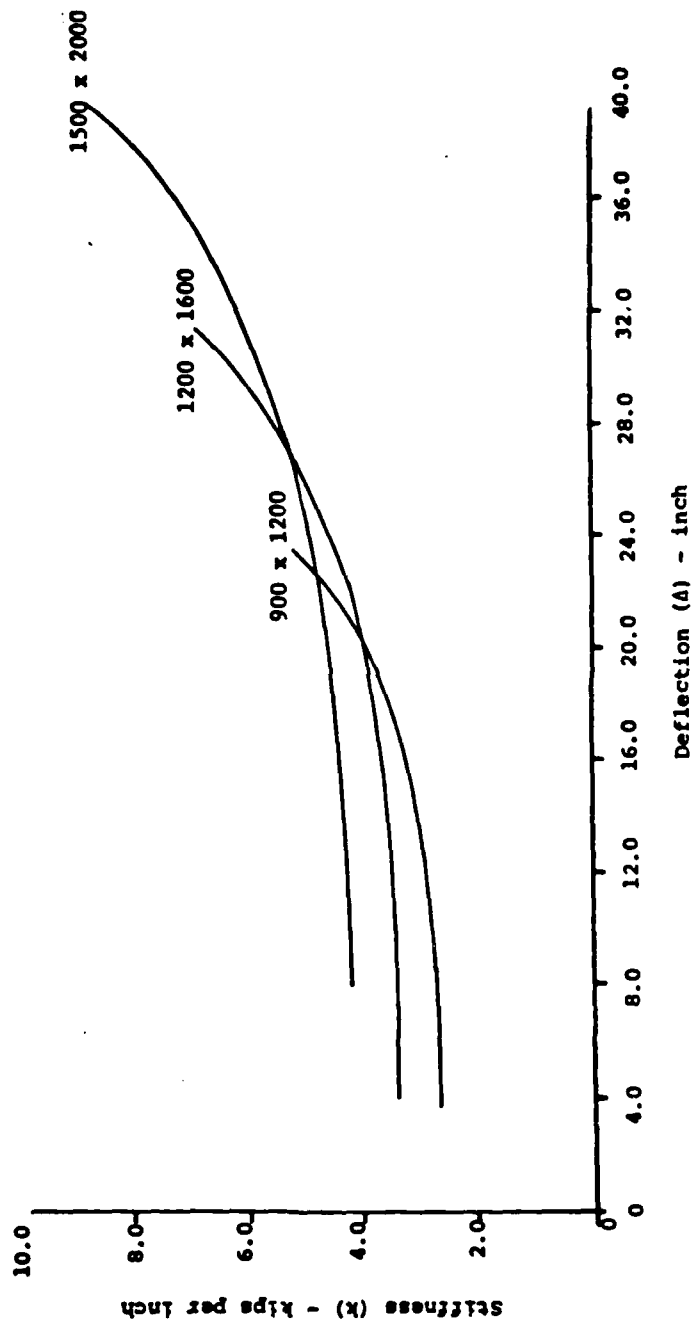
FIG. I-K-8: Stiffness vs. Deflection for Yokohama Air Blocks up to 1500 x 2000

312

APPENDIX II

REFERENCES

1. State-of-the-Art-Bridge Protective Devices, United States Coast Guard Contract CG-71955-A.

2. A. DeQuinn, "Design and Construction of Ports and Marine Structures," McGraw Hill Book Co., N.Y., 1972.

3. C. P. Heins, Applied Plate Theory for the Engineer, Lexington Books, Lexington, Mass., 1976.

APPENDIX III

NOTATIONS

M = mass of ship (W/g)

W = weight of ship

g = gravity (32.2 ft/sec^2)

Δ_s = deformation of fender systems at point of impact

$v_i v_f$ = initial and final velocity of ship

E = modulus of elasticity

I = moment of inertia of pile or waler

L = cantilever height of pile

k = spring constant of fender

D.F. = load distribution factor

M = induced pile moment

F_a = applied force to pile due to ship

F_r = resisting pile force

S = section modulus of pile

C_H = hydrodynamic coefficient

C_E = eccentricity coefficient of ship and fendering

C_s = softness coefficient of ship

C_c = configuration coefficient of ship

E_{in} = input energy due to ship

E_o = output energy available from pile

Δ_p = single pile deformation

Δ_f = fender deformation

F = applied force to pile due to ship

q, q_x, q_y = total external uniform load, and load on waler and pile respectively

w = lateral deformation of grid

x = horizontal coordinate

y = vertical coordinate

D_x = grid stiffness in x direction = $EI_x/\lambda y$

D_y = grid stiffness in y direction = $EI_y/\lambda x$

$\sigma = D_x/D_y$

$n = \lambda x/\lambda y$

REFERENCES

1. Public Works Maintenance-Wharfbuilding; "Structural Timbers-Fender Systems", U.S. Navy Wharfbuilding Handbook 1961; pp. 276-280.

2. Gower, L., Mardel, C. and Heathorn, W.; "The Behavior of Piles in Maritime Works", Insititute of Civil Engineers: Behavior of Piles; Paper 14, pp. 153-159.

3. Amer. Assoc. of Port Authorities; Port Design and Construction; ppl 140-152, 108-119.

4. Morison, J.R., Johnson, J.W., and O'Brien, M.P.; "Experimental Studies of Forces on Piles"; Coastal Engineering; pp. 340-369.

5. Reese, Lymon C. and Haliburton, T.A.; "Dynamic Response and Stability of Piers and Piles"; ASCE Proc. (Waterways 2) Vol. 89; May 1963, pp. 85-89.

6. Michalos, James; "Dynamic Response and Stability of Piers and Piles"; ASCE Proc. (Waterways 3) Vo. 88; August 1962; pp. 61-83.

7. Wakeman, C.M., Dockweiler, E.V., Stover, H.E. and Whiteneck. L.L.; "Use of Concrete in Marine Environments"; Journal of the American Concrete Institute; April 1958; Vol. 29; pp. 841-856.

8. Seiler, J.F. and Keeney, W. D.; "The Efficiency of Piles in Groups"; Wood Preserving News; November 1944; pp.109-118.

9. Praeger, E.H.; "Energy Absorption by the Pier and Wharf Structure"; Princeton Conference on Berthing in Exposed Locations.

10. Kleiner; "Construction of Dolphins in the Martinsa Bay"; Papers of 5th International Harbor Congress.

11. Volse, Louis A.; "Docking Fenders to Pier Protection"; Engineering News-Record; Vol. 160, No. 19; May 15, 1958; pp. 40-44.

12. Weis, John and Blancato, F.; "A Breasting Dolphin for Berthing Super Tankers"; ASCE Proc. (Waterways 3), September 1959; pp. 183-195.

13. Shu-t'len Li, F. and Venkataswamy Ramakrishnan, M.; "Ultimate Energy Design of Prestressed Concrete Fender Piling"; ASCE Proc. (Waterways 4) Vol. 97; November 1971; pp. 647-662.

14. Shu-t'len Li, F.; "Operative Energy Concept in Marine Fendering"; ASCE Proc. (Waterways 3) Vol. 87; August 1961; pp. 1-28.

15. Shu-t'len Li, F.; "Operative Energy Concept in Marine Fendering"; ASCE Proc. (Waterways 1) Vol. 89; February 1963; pp. 37-50.

16. Lewis, Edward V. and Borg, Sidney; "Energy Absorption by the Ship"; Princeton Conference on Berthing in Exposed Locations; pp 69-86.

17. Baker, A.L.L.; "Gravity Fenders"; Princeton Conference on Berthing in Exposed Locations; pp. 97-106.

18. Broersma, G. and Middelbiik, C.G.; "Middlebeek Fender, Naval Engineers Journal"; April 1971; pp. 83-91.

19. Dent, G.E. and Saurin, B.F.; "Tanker Terminals-Berthing Structures"; Institute of Civil Engineers: Tankers and Bulk Carrier Terminals.

20. Hopkins, David A.; "The Design of Piers, Jetties and Dolphins", ASCE Proc. (Maritime St. #2846) June 1955; pp. 22-38.

21. Little, Donald Hamish; "Some Designf for Flexible Fenders"; ASCE Proc. (Maritime St. #21) October 21, 1952; pp. 42-105.

22. Levinton, Zusse; "Elastic Fender Systems for Wharves"; Princeton Conference on Berthing in Exposed Locations; pp. 87-95.

23. Palmer, Robert W. Blancato, Virgil; "New Retractable Marine Fender System"; ASCE Proc. (Waterways #1513) January 1958; p. 1513-1 to 1513-8.

24. Picco, John and Blancato, Virgil; "Resilient Ferry Slip with Retractable Fender System"; August 1968, pp. 297-303.

25. Quinn, A.; Design and Construction of Ports and Marine Structures; McGraw-Hill, 3rd Edition; 1976; New York, New York.

26. Stracke, F.H.; "Offshore Mooring Facilities for Tankers up to 100,000 Dead Weight Ton Capacity"; Princeton Conference on Berthing in Exposed Locations, ppl 157-172.

27. "Heavy Duty Fendering"; Tanker and Bulk Carrier, February 1973; pp. 20-22.

28. Leimdorfer, P; "On the Selection of a Pile Type"; Acier/Stahl/Steel; September 1971; pp.369-377.

29. "The Fenders Retract"; Wood Preserving News; June 1971; pp. 4-7.

30. Ford, D.B., Young, B.O. and Waler, G.W.; "Hi-Dro Cushion Camel-A New Floating Fender Concept"; Conference on Coastal Engineering, London; September 1968; pp. 1185-1199.

31. Tam, W.A.; "Dynamic Mooring and Fendering System"; Offshore Technology Conference 1971; April 1971; pp. 53-62.

32. Toppler, J.F., Harris, H.R., and Weiersma, J.; "Planning and Design of Fixed Berth Stru-tures for 300,000 to 500,000 DWT Tankers"; Offshore Technology Conference, May 1972; pp. 279-294.

33. Powell, R.G. and Carle, R.B.; "The Use of Hydraulic Cushioning in the Docking of Super Tankers"; Offshore Technology Conference; May 1972; pp. 769-776.

34. Svendsen, I.A. and Jensen, J.V.; "The Form and Dimension of Fender Front Structures"; Dock and Harbour Authority; June 1970; pp. 65-69.

35. Terrell, M.; "A New Look at Fendering Systems"; Dock and Harbour Authority; May 1972; pp. 9-11.

36. Bijlsma, T.J.; "Super Fenders for Super Tankers"; Dock and Harbour Authority; April 1970; pp. 509-510.

37. Atack, D.C. and Kohring, W.; "Berthing and Mooring Systems for Mammoth Ships"; Dock and Harbour Authority; October 1970, pp. 241-242.

38. Svendsen, I.A.; "measurement of Impact Energies on Fenders"; Dock and Harbour Authority; September 1970; pp. 180-8.

39. Institute of Marine Engineers; "Offshore Mooring Fenders for ULCC's"; Marine Engineers Review; October 1973; P. 97.

40. Analytical Treatment of Problems of Berthing and Mooring Ships, NATO Advanced Study Institute.

41. American Association of Port Authorities, Inc.)AAPA), 1973, Port Planning, Desing and Construction, prepared by Committee IV, Construction & Maintenance, Washington, D.C.

42. Baker, A.L.L., 1953, Paper to the XVIII International Navigation Congress, Rome.

43. Brolsma, J.H., Hirs, J.A., and Langeveld, J.M., 1977, "On Fender Design and Berthing Velocities," 24th International Navigation Congress, Section II, Subject 4, Leningrad, pp. 87-99.

44. Bruun, P., 1976, Port Engineering, Gulf Publishing Co., Houston, Texas.

45. Costa, F.V.m 1964, "The Berthing Ship," The Dock and Harbour Authority, Vol. XLV, May, pp. 22-26, June, pp/ 49-53, July, pp. 90-94.

46. Dent, G.E., and Saurin, B.F., 1969, "Tanker terminals- berthing structures," Conference on Tanker and Bulk Carrier Terminals, The Institution of Civil Engineers, November 13, pp. 49-59.

47. Girgrah, M., 1977, "Practical Aspects of Dock Fender Design," 24th International Navigation Congress, Section II, Subject 4, Leningrad, pp. 5-13.

48. Goldman, J. 1977. Presidents of Friede and Goldman, Naval Architects and Marine Engineers, interviewed December 9.

49. Han, E.H. and Padron, D.V. 1978. Factors Affecting the Design and Construction of Offshore Terminals, Paper presented at meeting of the New York Metropolitan Section, Society of Naval Architects and Marine Engineers, February 15, 45 pages.

50. Horeczko, G. 1978. "Plastic protection for wood piles, "American Seaport, February, p. 24.

51. Lackner, E., and Wirsbitzki, D., 1974, "Fendering for Bulk Carrier Ports and Container Terminals, "Sixth International Harbor Congress, Section 2.19, May 12-18, 9 pp.

52. Lee, T.T., 1965, A Study of Effective Fender Systems for Navy Piers and Wharves, Technical Report R 312 prepared for U S. Naval Civil Engineering Laboratory, Port Hueneme, Calif.,   ii, 114 pages.

53. Lisnyk, J.A. 1975. "Projected Ship Types to the Year 2000",Ship Structure Symposium Proceedings, Octover 6-8, Washington D.C., pp. Q1-Q13.

54. Lord Corporation, 1977, Lord Marine Fender Manual, September 15.

55. Marine Engineering/Log. 1976. "LASH takes on lighters and heavyweights in moving NGL plant to Singapore", Vol. 81, No. 6, June, pp. 44 & 45.

56. Marine Engineering/Log. 1976. "U.S. Merchant Shipbuilding, 1607-1976". Vol. 81, No. 9, August, pp. 65-77, 172.

57. Maritime Administration (MarAd). 1965-1977. Merchant Fleets of the World - Oceangoing Steam and Motor Ships of 1,000 Gross Tons and over as of December 31, 19--, U.S. Department of Commerce, publish annually, Washington, D.C.

58. Meyers, J.J., Holm, C.H., and McAllister, R.F., 1969, "Wind and Wave Loads," Handbook of Ocean and Underwater Engineering, McGraw-Hill.

59. Minikin, R.R., 1950 & 1963. Winds, Waves and Maritime Structures, Charles Griffin & Co., London, 1950 (1st Edition) pp. 162-212 and 1963 (2nd Revised Edition) pp. 183-233.

60. Nelson, W.L., 1977. "What are tanker sizes?" The Oil and Gas Journal, Vol. 75, No. 38, September 12, pp. 128 & 129.

61. Nickels, F.J. 1975. "Marine - Port Technology Forecasts and Demand Analyses", Port System Study for the Public Ports of Washington State and Portland Oregon, Volume II, Technical Supplement, Part 5, prepared for Maritime Administration, U.S. Department of Commerce, March 31, p. 117.

62. Oil Companies International Marine Forum (OCIMF), 1977, Prediction of Wind and Current Loads on VLCC's, London

63. Piaseckyj, P.J., 1977, "State-of-the-Art of Fender Design," 24th International Navigation Congress, Section II, Subject 4, Leningrad, pp. 133-143.

64. Quinn, A. DeF., 1961, Design and Construction of Ports and Marine Structures, McGraw-Hill, New York, 531 pages.

65. Rosenblatt, M. & Son, Inc. 1978. Letter dated January 20, in response to future ship size inquiry.

66. Ross, D., 1975. Trends in Merchant Shipping (1969-1980), performed under contract No. N00123-75-C-0403 for the Naval Undersea Center, April 15, 89.

67. Saurin, B.F., 1963, Paper to the Sixth World Petroleum Congress, Frankfurt.

68. Seaward International, Inc., 1977, Sea Cushion Marine Fenders, product catalog SCTM-4(5-77), 51 pages.

69. Seibu Polumer Chemical Co., Ltd., 1977, Seibu Rubber Dock Fenders, manufacturer's catalogue.

70. Stieff, Jr., J.L. and Bayle, J.J., Year Unknown. "Effect of Fungicides on Natural and Synthetic Rubber," Industrial and Engineering Chemistry, Vol. 39, No. 9, pp. 1136-1138.

71. U.S. Senate, Committee on Interior and Insular Affairs, 1974. Deepwater Port Policy Issues, 93rd Congress, 2nd Session, Washington, D.C., 102 pages

72. Vredestein, B.V., 1977. Rubber Dock Fenders, manufacturer's catalog.

```
OLD *INPUT
LIST
FILE    *INPUT


0010 REM --------------------------------------------------------------
0020 REM INPUT PROGRAM
0030 REM --------------------------------------------------------------
0040 DCL SINGLE
0050 FILES INPUT
0060 DCL 40A$,40B$(),40C$(),40D$(),50R$
0070 REM --------------------------------------------------------------
0080 REM DIMENSIONING OF ARRAYS
0090 DIM G(40),R(40),N(40),X(10),Y(10),M(10),E(10),F(10)
0100 REM --------------------------------------------------------------
0150 LET R$="MODIFY INPUT (F1=YES,F2=NO)"
0200 FKEY #1,YES:
0205 FKEY #2,NO:
0500 GOSUB 9000
0510 PRINT TAB(25);"FENDERING SYSTEM DATA INPUT"
0520 PRINT TAB(25);"_____ _____ ____ _____"
0530 GOSUB 9040
0540 PRINT TAB(6);"INPUT INCLUDES THE FOLLOWING GENERAL CATEGORIES OF";
0550 PRINT " INFORMATION:"
0555 PRINT
0560 PRINT TAB(10);"   I.   JOB NAME"
0570 PRINT TAB(10);"  II.   OPTIONS"
0580 PRINT TAB(10);" III.   SHIP DATA"
0590 PRINT TAB(10);"  IV.   LOAD DATA"
0600 PRINT TAB(10);"   V.   PILE DATA"
0610 PRINT TAB(10);"  VI.   FENDER DATA"
0620 PRINT TAB(10);" VII.   SYSTEM CONFIGURATION DATA"
0630 PRINT TAB(10);"VIII.   BEAM DATA"
0640 PRINT TAB(10);"  IX.   JOINT COORDINATE DATA"
0650 PRINT TAB(10);"   X.   RIGID SUPPORT DATA"
0655 PRINT
0656 PRINT TAB(6);"FOR DETAILED EXPLANATION OF INPUT REFER TO DOCUMENTATION."
0657 PRINT
0660 GOSUB 9080
0670 DISP "ENTER JOB NAME(40 CHAR. MAX.)";
0680 RKB A$
0681 PRINT TAB(34);"I. JOB NAME"
0682 PRINT TAB(34);"__ ___ ____"
0683 PRINT
0684 PRINT TAB(22);A$
0685 GOSUB 9080
0686 DISP R$;
0687 INPUT S$
0688 IF S$="YES" THEN 670
0690 PRINT TAB(34);"II. OPTIONS"
0695 PRINT TAB(34);"___ _____"
0700 PRINT
0710 PRINT TAB(5);"OPTION 1"
0720 PRINT TAB(7);"1. ONE OR MORE VERTICAL PILES"
0730 PRINT TAB(7);"2. TWO BATTERED PILES"
0740 PRINT TAB(7);"3. GENERAL PILE CONFIGURATION"
0750 PRINT TAB(5);"OPTION 2"
0760 PRINT TAB(7);"1. REGULAR RUBBER FENDER"
0770 PRINT TAB(7);"2. GRAVITY-RETRACTABLE FENDER"
0780 PRINT TAB(7);"3. NO FENDER"
```

000001

```
0790 PRINT TAB(5);"OPTION 3"
0800 PRINT TAB(7);"1. JOINT COORDINATED GENERATED INTERNALLY"
0810 PRINT TAB(7);"2. JOINT COORDINATED INPUT"
0820 PRINT TAB(5);"OPTION 4"
0830 PRINT TAB(7);"1. DEFLECTIONS ONLY OUTPUT"
0840 PRINT TAB(7);"2. DEFLECTIONS AND SPRING CONSTANTS OUTPUT"
0850 PRINT TAB(5);"OPTION 5"
0860 PRINT TAB(7);"1. PILE GROUP ANALYSIS OUTPUT SUPPRESSED"
0870 PRINT TAB(7);"2. PILE GROUP ANALYSIS OUTPUT NOT SUPPRESSED"
0880 PRINT TAB(5);"OPTION 6"
0890 PRINT TAB(7);"1. JOINT DISPLACEMENT TABLE NOT OUTPUT"
0900 PRINT TAB(7);"2. JOINT DISPLACEMENT TABLE OUTPUT"
0910 PRINT TAB(5);"OPTION 7"
0920 PRINT TAB(7);"1. NO RIGID SUPPORTS"
0930 PRINT TAB(7);"2. ONE OR MORE RIGID SUPPORTS"
0940 GOSUB 9080
0950 LET B$(1)="  : ENTER 1,2, OR 3"
0960 LET B$(2)="  : ENTER 1 OR 2"
0970 LET B$(3)="INPUT ERROR"
0980 GOTO 1020
0990 DISP B$(3);B$(1);
1000 INPUT I1
1010 GOTO 1040
1020 DISP "OPTION 1";B$(1);
1030 INPUT I1
1040 IF I1<1 THEN 990
1050 IF I1>3 THEN 990
1060 GOTO 1100
1070 DISP B$(3);B$(1);
1080 INPUT I2
1090 GOTO 1120
1100 DISP "OPTION 2";B$(1);
1110 INPUT I2
1120 IF I2<1 THEN 1070
1130 IF I2>3 THEN 1070
1140 GOTO 1180
1150 DISP B$(3);B$(2);
1160 INPUT I3
1170 GOTO 1200
1180 DISP "OPTION 3";B$(2);
1190 INPUT I3
1200 IF I3<1 THEN 1150
1210 IF I3>2 THEN 1150
1220 GOTO 1260
1230 DISP B$(3);B$(2);
1240 INPUT I4
1250 GOTO 1280
1260 DISP "OPTION 4";B$(2);
1270 INPUT I4
1280 IF I4<1 THEN 1230
1290 IF I4>2 THEN 1230
1300 GOTO 1340
1310 DISP B$(3);B$(2);
1320 INPUT I5
1330 GOTO 1360
1340 DISP "OPTION 5";B$(2);
1350 INPUT I5
1360 IF I5<1 THEN 1310
1370 IF I5>2 THEN 1310
```

```
1380 GOTO 1420
1390 DISP B$(3),B$(2),
1400 INPUT I7
1410 GOTO 1440
1420 DISP "OPTION 6";B$(2),
1430 INPUT I7
1440 IF I7<1 THEN 1390
1450 IF I7>2 THEN 1390
1460 GOTO 1500
1470 DISP B$(3);B$(2);
1480 INPUT U1
1490 GOTO 1520
1500 DISP "OPTION 7";B$(2);
1510 INPUT U1
1520 IF U1<1 THEN 1470
1530 IF U1>2 THEN 1470
1535 DISP R$;
1536 INPUT S$
1537 IF S$="YES" THEN 1020
1540 PRINT TAB(33);"III. SHIP DATA"
1550 PRINT TAB(33);"____ ____ ____"
1560 PRINT
1561 PRINT TAB(10);"VARIABLE";TAB(50);"UNITS"
1562 PRINT
1570 PRINT TAB(10);"WEIGHT";TAB(50),"TON(SHORT)"
1580 PRINT TAB(10);"VELOCITY";TAB(50);"KNOT"
1590 GOSUB 9080
1600 DISP "ENTER WEIGHT OF SHIP";
1610 INPUT W
1620 DISP "ENTER VELOCITY OF SHIP";
1630 INPUT V2
1632 DISP R$;
1633 INPUT S$
1634 IF S$="YES" THEN 1600
1640 PRINT TAB(33);"IV. LOAD DATA"
1650 PRINT TAB(33);"___ ____ ____"
1655 PRINT
1656 PRINT
1660 PRINT TAB(10);"VARIABLE";TAB(50);"UNITS"
1665 PRINT
1670 PRINT TAB(10);"LOAD POINT"
1680 PRINT TAB(10);"ANGLE OF IMPACT";TAB(50),"DEGREE"
1690 PRINT TAB(10);"ANGLE BETWEEN LOAD AND X-AXIS";TAB(50),"DEGREE"
1700 GOSUB 9080
1710 DISP "ENTER LOAD POINT";
1720 INPUT L2
1730 DISP "ENTER ANGLE OF IMPACT";
1740 INPUT A6
1750 DISP "ENTER ANGLE BETWEEN LOAD AND X-AXIS";
1760 INPUT P2
1762 DISP R$;
1763 INPUT S$
1764 IF S$="YES" THEN 1710
1770 PRINT TAB(34);"V. PILE DATA"
1780 PRINT TAB(34);"__ ____ ____"
1790 PRINT
1800 PRINT TAB(10);"VARIABLE";TAB(50);"UNITS"
1805 PRINT
1810 PRINT TAB(10);"SUBGRAGE MODULUS";TAB(50);"KIP/FOOT**3"
1820 PRINT TAB(10);"TORSIONAL MODULUS";TAB(50);"KIP/INCH**2"
1830 PRINT TAB(10);"MODULUS OF ELASTICITY";TAB(50),"KIP/INCH**2"
```

009003

```
1840 GOSUB 9080
1850 DISP "ENTER SUBGRADE MODULUS";
1860 INPUT G1
1870 DISP "ENTER TORSIONAL MODULUS";
1880 INPUT G3
1890 DISP "ENTER MODULUS OF ELASTICITY";
1900 INPUT E1
1902 DISP R$,
1903 INPUT S$
1904 IF S$="YES" THEN 1850
1910 PRINT TAB(29),"V. PILE DATA(CONT.)"
1920 PRINT TAB(29),"__ ____ _____"
1930 PRINT
1940 PRINT TAB(10),"VARIABLE";TAB(50),"UNITS"
1945 PRINT
1950 LET B$(4)="NUMBER OF PILES"
1960 LET B$(5)="PILE NUMBER"
1970 LET B$(6)="LENGTH"
1980 LET B$(7)="CANTILEVER LENGTH"
1990 LET B$(8)="PROJECTED WIDTH IN X-X DIRECTION"
2000 LET B$(9)="PROJECTED WIDTH IN Y-Y DIRECTION"
2010 LET B$(10)="MOMENT OF INERTIA ABOUT X-X AXIS"
2020 LET C$(1)="MOMENT OF INERTIA ABOUT Y-Y AXIS"
2030 LET C$(2)="POLAR MOMENT OF INERTIA"
2040 LET C$(3)="CROSS-SECTIONAL AREA"
2050 LET C$(4)="YIELD STRESS"
2060 LET C$(5)="NEURTAL-AXIS-OUTER-FIBER LENGTH"
2070 LET C$(6)="VERTICAL LOAD"
2080 ON I1 GOTO 2090,2230,2370
2090 PRINT TAB(10),"NUMBER OF PILES",TAB(60),"(<=10)"
2100 PRINT TAB(10),"SPACING",TAB(50),"INCH"
2110 PRINT TAB(10),B$(6),TAB(50),"FOOT"
2120 PRINT TAB(10),B$(7),TAB(50),"FOOT"
2130 PRINT TAB(10),B$(8),TAB(50),"INCH"
2140 PRINT TAB(10),B$(9),TAB(50),"INCH"
2150 PRINT TAB(10),B$(10),TAB(50),"INCH**4"
2160 PRINT TAB(10),C$(1),TAB(50),"INCH**4"
2170 PRINT TAB(10),C$(2),TAB(50),"INCH**4"
2180 PRINT TAB(10),C$(3),TAB(50),"INCH**2"
2190 PRINT TAB(10),C$(4),TAB(50),"KIP/INCH**2"
2200 PRINT TAB(10),C$(5),TAB(50),"INCH"
2210 PRINT TAB(10),C$(6),TAB(50),"KIP"
2220 GOTO 2750
2230 PRINT TAB(10),"SLOPE"
2240 PRINT TAB(10),B$(6),TAB(50),"FOOT"
2250 PRINT TAB(10),B$(8),TAB(50),"INCH"
2260 PRINT TAB(10),B$(9),TAB(50),"INCH"
2270 PRINT TAB(10),B$(10),TAB(50),"INCH**4"
2280 PRINT TAB(10),C$(1),TAB(50),"INCH**4"
2290 PRINT TAB(10),C$(2),TAB(50),"INCH**4"
2300 PRINT TAB(10),C$(3),TAB(50),"INCH**2"
2310 PRINT TAB(10),C$(4),TAB(50),"KIP/INCH**2"
2320 PRINT TAB(10),C$(5),TAB(50),"INCH"
2330 PRINT TAB(10),C$(6),TAB(50),"KIP"
2340 PRINT
2350 PRINT TAB(10),"PILE NUMBER"
2355 PRINT TAB(10),"CATILEVER LENGTH",TAB(50),"FOOT"
2360 GOTO 2750
2370 PRINT TAB(10),"NUMBER OF PILES",TAB(60),"(<=10)"
2400 PRINT TAB(10),"SHAPE FACTOR"
2410 PRINT TAB(10),"VERTICAL PILE LOGIC"
```

000004

```
2420 PRINT TAB(10);"NUMBER OF SAMPLE POINT",TAB(60);"(<=10)"
2430 PRINT TAB(10);B$(6);TAB(50);"FOOT"
2440 PRINT TAB(10);B$(8);TAB(50);"INCH"
2445 PRINT TAB(10);B$(9);TAB(50);"INCH"
2450 PRINT TAB(10);B$(10);TAB(50);"INCH**4"
2460 PRINT TAB(10);C$(1);TAB(50);"INCH**4"
2470 PRINT TAB(10);C$(2);TAB(50);"INCH**4"
2480 PRINT TAB(10);C$(3);TAB(50);"INCH**2"
2490 PRINT TAB(10);C$(4);TAB(50);"KIP/INCH**2"
2500 PRINT TAB(10);C$(5);TAB(50);"INCH"
2510 PRINT TAB(10);C$(6);TAB(50);"KIP"
2580 PRINT
2590 PRINT TAB(26);"INPUT ONCE FOR EACH PILE"
2600 PRINT
2610 PRINT TAB(10);"PILE NUMBER"
2620 PRINT TAB(10);"X-COORDINATE";TAB(50);"INCH"
2630 PRINT TAB(10);"Y-COORDINATE";TAB(50);"INCH"
2640 PRINT TAB(10);"Z-COORDINATE";TAB(50);"INCH"
2650 PRINT TAB(10);"SLOPE"
2660 PRINT TAB(10);"ANGLE";TAB(50);"DEGREE"
2670 PRINT TAB(10);"CANTILEVER LENGTH";TAB(50);"FOOT"
2680 PRINT
2690 PRINT TAB(17);"INPUT IF NO. OF SAMPLE POINTS GREATER THAN 0"
2700 PRINT
2710 PRINT TAB(10);"SAMPLE POINT NUMBER";TAB(60);"(<=10)"
2720 PRINT TAB(10);"X-COORDINATE";TAB(50);"INCH"
2730 PRINT TAB(10);"Y-COORDINATE";TAB(50);"INCH"
2740 PRINT TAB(10);"Z-COORDINATE";TAB(50);"INCH"
2750 GOSUB 9080
2760 LET C$(7)="ENTER LENGHT"
2770 LET C$(8)="ENTER CANTILEVER LENGTH"
2780 LET C$(9)="ENTER PROJ. WIDTH X-X DIRECT."
2790 LET C$(10)="ENTER PROJ. WIDHT Y-Y DIRECT."
2800 LET D$(1)="ENTER MOM. OF I. ABOUT X-X AXIS"
2810 LET D$(2)="ENTER MOM. OF I. ABOUT Y-Y AXIS"
2820 LET D$(3)="ENTER POLAR MOMENT OF I."
2830 LET D$(4)="ENTER CROSS-SECT. AREA"
2840 LET D$(5)="ENTER YIELD STRESS"
2850 LET D$(6)="ENTER NEUTRAL-AXIS-OUTER-FIBER-LENGTH"
2860 LET D$(7)="ENTER VERTICAL LOAD"
2870 ON I1 GOTO 2880,3210,3480
2880 GOTO 2920
2890 DISP B$(3);": ENTER 1 TO 10";
2900 INPUT K
2910 GOTO 2940
2920 DISP "ENTER NUMBER OF PILES";
2930 INPUT K
2940 IF K>10 THEN 2890
2950 IF K<1 THEN 2890
2960 DISP "ENTER PILE SPACING";
2970 INPUT S6
2980 DISP C$(7);
2990 INPUT Z1
3000 DISP C$(8);
3010 INPUT Z8
3020 DISP C$(9);
3030 INPUT Z6
3040 DISP C$(10);
3050 INPUT Z7
3060 DISP D$(1);
3070 INPUT Z3
```

```
3080 DISP D$(2);
3090 INPUT Z4
3100 DISP D$(3);
3110 INPUT Z2
3120 DISP D$(4);
3130 INPUT Z5
3140 DISP D$(5);
3150 INPUT Z9
3160 DISP D$(6);
3170 INPUT Y1
3180 DISP D$(7);
3190 INPUT Y2
3200 GOTO 4190
3210 DISP "ENTER SLOPE";
3220 INPUT H2
3230 DISP C$(7);
3240 INPUT A7
3250 DISP C$(9);
3260 INPUT D1
3270 DISP C$(10);
3280 INPUT D2
3290 DISP D$(1);
3300 INPUT A8
3310 DISP D$(2);
3320 INPUT B3
3330 DISP D$(3);
3340 INPUT A9
3350 DISP D$(4);
3360 INPUT B4
3370 DISP D$(5);
3380 INPUT B5
3390 DISP D$(6);
3400 INPUT B6
3410 DISP D$(7);
3420 INPUT C3
3430 FOR J=1 TO 2 STEP 1
3440 DISP "ENTER PILE NO., CANT. LENGTH";
3450 INPUT J,F(J)
3460 NEXT J
3470 GOTO 4190
3480 GOTO 3520
3490 DISP B$(3);": ENTER 1 TO 10";
3500 INPUT K
3510 GOTO 3540
3520 DISP "ENTER NUMBER OF PILES";
3530 INPUT K
3540 IF K<1 THEN 3490
3550 IF K>10 THEN 3490
3560 LET N7=3
3570 LET N8=1
3592 GOTO 3600
3594 DISP B$(3);": ENTER 1 TO 2";
3596 INPUT K5
3598 GOTO 3604
3600 DISP "ENTER SHAPE FACTOR";
3602 INPUT K5
3604 IF K5<1 THEN 3594
3606 IF K5>2 THEN 3594
3608 GOTO 3616
3610 DISP B$(3);":ENTER 0 OR 1";
3612 INPUT K3
```

```
3614 GOTO 3620
3616 DISP " ENTER VERTICAL PILE LOGIC";
3618 INPUT K3
3620 IF K3<0 THEN 3610
3622 IF K3>1 THEN 3610
3640 GOTO 3780
3750 DISP B$(3);"ENTER 1 TO 10";
3760 INPUT N9
3770 GOTO 3800
3780 DISP "ENTER NO. OF SAMPLE POINTS";
3790 INPUT N9
3800 IF N9<0 THEN 3750
3810 IF N9>10 THEN 3750
3820 DISP C$(7);
3830 INPUT A7
3840 DISP C$(9);
3850 INPUT D1
3860 DISP C$(10);
3870 INPUT D2
3880 DISP D$(1);
3890 INPUT A8
3900 DISP D$(2);
3910 INPUT B3
3920 DISP D$(3);
3930 INPUT A9
3940 DISP D$(4);
3950 INPUT B4
3960 DISP D$(5);
3970 INPUT B5
3980 DISP D$(6);
3990 INPUT B6
4000 DISP D$(7);
4010 INPUT C3
4100 LET Q(1)=1.0
4110 LET Q(2)=Q(3)=0.0
4130 LET Q(4)=Q(5)=Q(6)=0.0
4131 FOR J=1 TO K STEP 1
4132 DISP "ENTER PILE NO.,X,Y,AND Z COOR.";
4133 INPUT J,X(J),Y(J),Z
4134 NEXT J
4135 FOR J=1 TO K STEP 1
4136 DISP "ENTER PILE NO.,SLOPE,ANGLE,CANT. LENGTH";
4137 INPUT J,M(J),E(J),F(J)
4138 NEXT J
4140 IF N9=0 THEN 4190
4150 FOR J=1 TO N9 STEP 1
4160 DISP "ENTER SAMPLE POINT X,Y,Z COOR.";
4170 INPUT J,P(J,1),P(J,2),P(J,3)
4180 NEXT J
4190 DISP R$;
4191 INPUT S$
4192 IF S$="YES" THEN 2870
4195 PRINT TAB(32);"VI. FENDER DATA"
4200 PRINT TAB(32);"___ _____ ____"
4210 PRINT
4220 PRINT TAB(10);"VARIABLE";TAB(50);"UNITS"
4230 PRINT
4240 ON I2 GOTO 4250,4380,4523
4250 PRINT TAB(10);"A-COEFFICIENT"
4260 PRINT TAB(10);"B-COEFFICIENT"
4270 PRINT TAB(10);"C-COEFFICIENT"
```

```
4280 PRINT TAB(10);"MAXIMUM DEFLECTION";TAB(50);"INCH"
4290 GOSUB 9080
4300 DISP "ENTER A-COEFFICIENT";
4310 INPUT A4
4320 DISP "ENTER B-COEFFICIENT";
4330 INPUT B2
4340 DISP "ENTER C-COEFFICIENT";
4350 INPUT C2
4360 DISP "ENTER MAXIMUM DEFLECTION";
4370 INPUT D3
4375 GOTO 4505
4380 PRINT TAB(10);"WEIGHT OF COUNTER-WEIGHT(C-W) AND FEND.";TAB(50);"KIP"
4390 PRINT TAB(10);"DISTANCE BETWEEN C-W AND SUPPORT";TAB(50);"INCH"
4400 PRINT TAB(10);"ANGLE BETWEEN TRACT OF C-W AND HORIZ.";TAB(50);"DEGREE"
4410 PRINT TAB(10);"COEFFICIENT OF FRICTION"
4420 GOSUB 9080
4430 DISP "ENTER WEIGHT";
4440 INPUT W3
4450 DISP "ENTER DISTANCE";
4460 INPUT F1
4470 DISP "ENTER ANGLE";
4480 INPUT T1
4490 DISP "ENTER COEFF. OF FRICTION";
4500 INPUT P3
4505 DISP R$;
4520 INPUT S$
4521 IF S$="YES" THEN 4240
4522 GOTO 4525
4523 PRINT TAB(10);"NO FENDER USED TO MODEL THIS SYSTEM"
4524 GOSUB 9000
4525 PRINT TAB(25);"VII. SYSTEM CONFIGURATION DATA"
4530 PRINT TAB(25);"____ _____ _____ ____"
4540 PRINT
4550 PRINT TAB(10);"VARIABLE";TAB(50);"UNITS"
4560 PRINT
4570 PRINT TAB(10);"NUMBER OF PILE GROUPS";TAB(60);"(<=12)"
4580 PRINT TAB(10);"NUMBER OF FENDERS";TAB(60);"(<=12)"
4590 PRINT TAB(10);"SPACING BETWEEN PILE GROUPS";TAB(50);"INCH"
4600 GOSUB 9080
4610 GOTO 4618
4612 DISP B$(3);": ENTER 1 TO 12";
4614 INPUT N6
4616 GOTO 4622
4618 DISP "ENTER NO. OF PILE GROUPS";
4620 INPUT N6
4622 IF N6>12 THEN 4612
4624 IF N6<1 THEN 4612
4626 GOTO 4634
4628 DISP B$(3);": ENTER 0 TO 12";
4630 INPUT N3
4632 GOTO 4638
4634 DISP "ENTER NO. OF FENDERS";
4636 INPUT N3
4638 IF N3>12 THEN 4628
4640 IF N3<0 THEN 4628
4650 DISP "ENTER SPACING";
4660 INPUT H3
4662 DISP R$;
4663 INPUT S$
4664 IF S$="YES" THEN 4618
4670 PRINT TAB(32);"VIII. BEAM DATA"
```

```
4680 PRINT TAB(32);"_____ ____ ____"
4690 PRINT
4700 LET D$(8)="MODULUS OF ELASTICITY"
4710 LET D$(9)="MOMENT OF INERTIA"
4720 LET D$(10)="AREA"
4730 PRINT TAB(31);"SUPPORT BEAMS(S.B.)"
4740 PRINT
4750 PRINT TAB(10);"VARIABLE";TAB(50);"UNITS"
4760 PRINT
4770 PRINT TAB(10);D$(8);TAB(50);"KIP/INCH**2"
4780 PRINT TAB(10);D$(9);TAB(50);"INCH**4"
4790 PRINT TAB(10);D$(10);TAB(50);"INCH**2"
4800 IF I2<>1 THEN 4890
4810 GOSUB 9040
4820 PRINT TAB(31);"FENDER BEAM(F.B.)"
4830 PRINT
4840 PRINT TAB(10);"VARIABLE";TAB(50);"UNITS"
4850 PRINT
4860 PRINT TAB(10);D$(8);TAB(50);"KIP/INCH**2"
4870 PRINT TAB(10);D$(9);TAB(50);"INCH**4"
4880 PRINT TAB(10);D$(10);TAB(50);"INCH**2"
4890 GOSUB 9080
4900 DISP "ENTER S.B. MODULUS OF ELAST.";
4910 INPUT E2
4920 DISP "ENTER S.B. MOMENT OF I.";
4930 INPUT R1
4940 DISP "ENTER S.B. AREA";
4950 INPUT R2
4960 IF I2<>1 THEN 5030
4970 DISP "ENTER F.B. MODULUS OF ELAST.";
4980 INPUT E3
4990 DISP "ENTER F.B. MOMENT OF I.";
5000 INPUT R3
5010 DISP "ENTER F.B. AREA";
5020 INPUT R4
5030 DISP R$;
5031 INPUT S$
5032 IF S$="YES" THEN 4900
5033 PRINT TAB(28);"IX. JOINT COORDINATE DATA"
5040 PRINT TAB(28);"___ _____ _____ ____"
5050 PRINT
5060 IF I3=1 THEN 5170
5070 IF I2=1 THEN 5100
5080 LET L3=N6*2+2
5090 GOTO 5110
5100 LET L3=3*N3+4-(N3-N6)
5110 PRINT TAB(10);"VARIABLE";TAB(50);"UNITS"
5120 PRINT
5130 PRINT TAB(10);"JOINT NUMBER";TAB(60);"(<=40)"
5140 PRINT TAB(10);"X-COORDINATE";TAB(50);"INCH"
5150 PRINT TAB(10);"Y-COORDINATE";TAB(50);"INCH"
5160 GOTO 5180
5170 PRINT TAB(21);"JOINT COORDINATES GENERATED INTERNALLY"
5180 GOSUB 9080
5190 IF I3=1 THEN 5240
5200 FOR J=1 TO L3 STEP 1
5210 DISP "ENTER JOINT NO.,X, AND Y COORD.";
5220 INPUT J,G(J),R(J)
5230 NEXT J
5231 DISP R$;
5232 INPUT S$
```

000009

```
5233 IF S$="YES" THEN 5200
5240 PRINT TAB(30);"X. RIGID SUPPORT DATA"
5250 PRINT TAB(30);"__ _____ _____ ____"
5260 PRINT
5270 IF U1=2 THEN 5300
5280 PRINT TAB(32);"NO RIGID SUPPORTS"
5290 GOTO 5490
5300 PRINT TAB(10);"VARIABLE";TAB(50);"UNITS"
5310 PRINT
5320 PRINT TAB(10);"NUMBER OF RIGID SUPPORTS";TAB(60);"(<=12)"
5330 PRINT TAB(10);"SPRING NUMBER"
5340 GOSUB 9000
5341 GOTO 5350
5342 DISP B$(3);": ENTER 1 TO 12";
5343 INPUT N5
5344 GOTO 5362
5350 DISP "ENTER NO. OF RIGID SUPPORTS";
5360 INPUT N5
5362 IF N5>12 THEN 5342
5370 IF N5=0 THEN 5490
5380 LET L4=(N5+13)/14
5390 LET L4=INT(L4)
5400 FOR I9=1 TO L3 STEP 1
5410 LET J=(I9-1)*14+1
5420 LET L5=J+13
5430 LET L5=INT(L5)
5440 FOR J9=J TO L5 STEP 1
5450 DISP "ENTER SPRING NUMBER";
5460 INPUT N(J9)
5470 NEXT J9
5480 NEXT I9
5481 DISP R$;
5482 INPUT S$
5483 IF S$="YES" THEN 5350
5490 GOTO 9198
9000 FOR I9=1 TO 5 STEP 1
9010 PRINT
9020 NEXT I9
9030 RETURN
9040 FOR I9=1 TO 2 STEP 1
9050 PRINT
9060 NEXT I9
9070 RETURN
9080 FOR I9=1 TO 10 STEP 1
9090 PRINT
9100 NEXT I9
9110 RETURN
9170 REM --------------------------------------
9180 REM WRITE INTO FILE INPUT
9190 REM --------------------------------------
9198 WRITE :1,A$
9200 WRITE :1,I1,I2,I3,I4,I5,I7,U1
9210 WRITE :1,U,U2,L2,A6,P2,G1,G3,E1
9220 ON I1 GOTO 9230,9270,9330
9230 WRITE :1,K,S6
9240 WRITE :1,Z1,Z8,Z6,Z7,Z3,Z4
9250 WRITE :1,Z2,Z5,Z9,Y1,Y2
9260 GOTO 9420
9270 WRITE :1,H2
9280 WRITE :1,A7,D1,D2,A8,B3,A9,B4,B5,B6,C3
9290 FOR J=1 TO 2 STEP 1
```

```
9300 WRITE :1,J,F(J)
9310 NEXT J
9320 GOTO 9420
9330 WRITE :1,K,N7,N8,K5,K3,N9
9340 WRITE :1,A7,D1,D2,A8,B3,A9,B4,B5,B6,C3
9350 FOR J=1 TO K STEP 1
9360 WRITE :1,J,X(J),Y(J),Z,M(J),E(J),F(J)
9365 NEXT J
9370 WRITE :1,Q(1),Q(2),Q(3),Q(4),Q(5),Q(6)
9380 IF N9=0 THEN 9420
9390 FOR J=1 TO N9 STEP 1
9400 WRITE :1,J,P(J,1),P(J,2),P(J,3)
9410 NEXT J
9420 IF I2<>1 THEN 9440
9430 WRITE :1,A4,B2,C2,D3
9440 IF I2<>2 THEN 9460
9450 WRITE :1,W3,F1,T1,P3
9460 WRITE :1,N6,N3,H3
9470 WRITE :1,E2,R1,R2
9480 IF I2<>1 THEN 9500
9490 WRITE :1,E3,R3,R4
9500 IF I3=1 THEN 9540
9510 FOR J=1 TO L3 STEP 1
9520 WRITE :1,J,G(J),R(J)
9530 NEXT J
9540 IF U1=1 THEN 9650
9550 WRITE :1,N5
9560 IF N5=0 THEN 9650
9570 FOR I9=1 TO L4 STEP 1
9580 LET J=I9-1+14+1
9590 LET L5=J+13
9600 LET L5=INT(L5)
9610 FOR J9=J TO L5 STEP 1
9620 WRITE :1,N(J9)
9630 NEXT J9
9640 NEXT I9
9650 REM ------------------------------------------------------------
9660 CHAIN "*MAINL"
9670 REM ------------------------------------------------------------
9999 END

END OF LISTING



FILE     *MAINL4


0005 REM ****************************************************************
0010 REM SUBROUTINE MAINL4(FROM 352 CONTINUE TO END)
0015 REM ****************************************************************
0020 FILES AR;BB
0025 DCL SINGLE
0030 SETW :1 TO 1
0035 SETW :2 TO 1
0040 REM ------------------------------------------------------------
0045 REM READ FROM FILES
0050 REM ------------------------------------------------------------
0055 FOR I9=1 TO 30 STEP 1
0060 READ :1,J(I9),L(I9)
0065 NEXT I9
0070 READ :1,N9
```

```
0075 FOR I9=1 TO N9 STEP 1
0080 READ :1,D(I9)
0085 NEXT I9
0090 READ :1,Y1
9095 FOR I9=1 TO Y1 STEP 1
0100 READ :1,S(I9)
0105 NEXT I9
0110 FOR I9=1 TO 10 STEP 1
0115 FOR J9=1 TO 60 STEP 1
0120 READ :1,H(I9,J9)
0125 NEXT J9
0130 NEXT I9
0135 FOR I9=1 TO 25 STEP 1
0140 READ :1,N(I9),T(I9),P(I9),V(I9),A(I9),F(I9),R(I9)
0145 NEXT I9
0150 READ :1,I1,I3,N2,I6,N3,N5,I,S2,P2,N6,K,C1,A1,B1,A2
0151 IF I1=1 THEN 155
0152 READ :1,I2
0155 FOR I9=1 TO 25 STEP 1
0160 FOR J9=1 TO 18 STEP 1
0165 READ :1,M(I9,J9)
0170 NEXT J9
0175 NEXT I9
0180 FOR I9=1 TO K STEP 1
0185 READ :1,E(I9)
0190 NEXT I9
0195 READ :2,I7,N1
0300 REM ----------------------------------------------------
0305 REM DIMENSIONING OF ARRAYS
0310 DIM M(25,18),N(25),T(25),D(25),V(25),A(25),F(25),R(25)
0315 DIM S(40),L(30),J(30),H(10,60),D(192),E(25),P(25),X(21),W(21),Y(21)
0320 REM ----------------------------------------------------
0500 IF I1<>1 THEN 510
0505 LET I2=3-3*I3
0510 LET I4=1
0515 IF N1=3 THEN 695
0520 FOR I9=1 TO N2 STEP I3
0525 LET I2=I2+3*I3
0530 IF L(I9)=0 THEN 690
0535 IF J(I9)=1 THEN 690
0540 LET I5=I2+1
0545 LET J1=I2*3
0550 LET J2=I5*3
0555 LET D1=(D(J2-1)-D(J1-1))↑2
0560 LET D2=(D(J2-2)-D(J1-2))↑2
0565 LET D3=SQR(D1+D2)
0570 IF I6=1 THEN 585
0575 LET D3=D3*2.0
0580 LET S(I9)=S(I9)/2.0
0585 LET S1=S(I9)
0590 LET D4=D3
0595 LET M1=N3*3+2+I9
0600 LET N4=INT((I9+(I3-1))/I3)
0605 LET J3=I2
0610 LET J4=I5
0615 IF I6<>0 THEN 645
0620 LET N4=M1-(3*N3+2)
0625 LET M1=N4+(N3+1)
0630 LET J3=2*N4
0635 LET J4=J3+1
```

000012

```
0640 GOTO 670
0645 IF I6<>1 THEN 670
0650 IF M5=0 THEN 670
0655 LET M1=N4+(3*N3+2)
0660 LET J3=5+(N4-1)*(2*M5+3)-2
0665 LET J4=J3+1
0670 GOTO 671
0671 FOR L9=1 TO 5 STEP 1
0672 PRINT
0673 NEXT L9
0675 REM --------------------------------------------------------
0680 GOSUB 1040
0685 REM --------------------------------------------------------
0690 NEXT I9
0695 GOTO 700
0700 IF I1<>1 THEN 710
0705 LET I=I-1
0710 IF I7=1 THEN 815
0715 FOR I9=1 TO 8 STEP 1
0720 PRINT
0725 NEXT I9
0730 PRINT TAB(28);"CONVERGENCE SUMMARY"
0735 PRINT TAB(28);"_____ _____"
0740 PRINT
0745 PRINT TAB(18);"NUMBER OF LOOPS";TAB(41);"DYNAMIC";TAB(56);"NUMBER OF LOOPS"
0750 PRINT TAB(6);"TIME";TAB(20);"FOR DYNAMIC";TAB(39);"CONVERGENCE";TAB(58);
0755 PRINT "FOR STATIC"
0757 PRINT TAB(5);"INSTANT";TAB(20);"CONVERGENCE";TAB(39);"LOOP NUMBER";TAB(57);
0759 PRINT "CONVERGENCE"
0760 FOR I9=1 TO 25 STEP 1
0765 IF M(I9,1)=0 THEN 815
0770 FOR J9=1 TO 18 STEP 1
0775 IF M(I9,J9)=0 THEN 810
0780 IF J9<>1 THEN 795
0785 PRINT USING 790,I9,M(I9),J9,M(I9,J9)
0790 :        ###                ###                ###                ####
0795 IF J9<=1 THEN 805
0800 PRINT USING 803,J9,M(I9,J9)
0803 :                                               ###                ####
0805 NEXT J9
0810 NEXT I9
0815 FOR I9=1 TO 8 STEP 1
0820 PRINT
0825 NEXT I9
0830 PRINT TAB(13);"OUTPUT OF DYNAMIC DATA AT THE POINT OF IMPACT"
0835 PRINT TAB(13);"_____ __ _____ ____ __ ___ _____ __ _____"
0840 PRINT
0845 PRINT TAB(5);"STEP";TAB(12);"TIME";TAB(21);"DEFL";TAB(26);"VELOCITY";
0847 PRINT TAB(37);"ACCELERATION";TAB(52);"FORCE";TAB(60);"SPRING K"
0849 PRINT TAB(6);"NO";TAB(12);"(SEC)";TAB(21);"(IN)";TAB(26);"(IN/SEC)";
0851 PRINT TAB(38);"(IN/SEC**2)";TAB(53);"(K)";TAB(61);"(K/IN)"
0855 FOR I9=1 TO I STEP 1
0860 PRINT USING 865,I9,T(I9),P(I9),V(I9),A(I9),F(I9),R(I9)
0865 :    ###    ##.### ####.## ####.##    ####.###    #####.##    ####.###
0870 NEXT I9
0875 LET I=I-1
0876 IF I<>0 THEN 880
0877 LET I=1
0880 LET E1=0.0
0885 FOR I9=1 TO 8 STEP 1
```

```
0890 PRINT
0895 NEXT I9
0900 PRINT TAB(12);"OUTPUT OF KINETIC AND POTENTIAL ENERGY FOR SYSTEM"
0905 PRINT TAB(12);"_____ __ _____ ___ _____ _____ ___ _____"
0910 PRINT
0915 PRINT TAB(5);"STEP";TAB(29);"KINETIC";TAB(44);"POTENTIAL";TAB(61);"TOTAL"
0917 PRINT TAB(6);"NO";TAB(17);"TIME";TAB(30);"ENERGY";TAB(46);"ENERGY";TAB(61);
0919 PRINT "PE+KE"
0921 PRINT TAB(17);"(SEC)";TAB(30);"(K*IN)";TAB(46);"(K*IN)";TAB(61);"(K*IN)"
0930 FOR I9=1 TO I STEP 1
0935 LET E2=S2*V(I9)↑2/2.0
0940 LET E3=E2+E1
0945 LET T1=E1
0950 PRINT USING 953,I9,T(I9),E2,E1,E3
0953 :     ###        ###.####     ########.###    ########.###   ########.###
0955 LET E1=E1+(F(I9)+F(I9+1))*(P(I9+1)-P(I9))/2.0
0960 NEXT I9
0965 LET T2=S2*V(1)↑2/2.0
0970 LET E4=(T2-T1)/T2*100.0
0975 FOR I9=1 TO 4 STEP 1
0980 PRINT
0985 NEXT I9
0990 PRINT USING 995,T2
0995 :                  TOTAL KINETIC ENERGY OF SHIP=   ########.## K**IN
1000 PRINT USING 1005,T1
1005 :              TOTAL POTENTIAL ENERGY OF FENDER=   ########.## K**IN
1006 FOR I9=1 TO 5 STEP 1
1007 PRINT
1008 NEXT I9
1009 PRINT TAB(20);"**********************************************"
1010 PRINT USING 1015,E4
1015 :                   *          ERROR=   #####.## PERCENT       *
1016 PRINT TAB(20);"**********************************************"
1020 GOTO 8000
1025 REM ------------------------------------------------------------
1030 REM SUBROUTINE PLA
1035 REM ------------------------------------------------------------
1040 IF I4=1 THEN 1055
1045 LET P1=P2
1046 REM PRINT "P2=";P2
1050 GOTO 1060
1055 LET P1=S1*D4
1060 GOTO 1065
1065 ON N6 GOTO 1070,1225
1070 LET K1=1
1075 LET P1=P1/K
1080 LET H1=E(K1)/20.0
1085 LET H2=-H1
1090 LET T3=P1*H(K1,K1*6+5)
1095 LET P3=C1/A1
1100 IF I4=1 THEN 1120
1105 PRINT TAB(31);"FAILED PILE"
1110 PRINT TAB(31);"_____ ____"
1115 GOTO 1130
1120 PRINT TAB(29);"REMAINING PILE"
1125 PRINT TAB(29);"_____ ____"
1130 PRINT
1135 PRINT USING 1137,M1
1137 :     MEMBER NUMBER    ####
1139 PRINT USING 1141,N4
```

000014

```
1141 :         SPRING NUMBER     ####
1143 PRINT USING 1145,J3
1145 :        STARTING JOINT    ####
1147 PRINT USING 1149,J4
1149 :         ENDING JOINT     ####
1151 PRINT USING 1153,P1
1153 :                  FORCE  #####.####  K
1155 PRINT
1157 PRINT
1165 PRINT TAB(5);"DISTANCE FROM";TAB(33);"HORIZONTAL";TAB(48);"VERTICAL"
1170 PRINT TAB(6);"TOP OF PILE";TAB(22);"MOMENT";TAB(35);"SHEAR";TAB(49);
1175 PRINT "SHEAR";TAB(61);"STRESS"
1176 PRINT TAB(9);"(FT)";TAB(22);"(FT*K)";TAB(36);"(K)";TAB(50);"(K)";TAB(59);
1178 PRINT "(K/IN**2)"
1180 FOR J9=1 TO 21 STEP 1
1185 LET H2=H2+H1
1190 LET X1=T3+P1*H2
1195 LET S4=P3+X1*B1/A2
1200 LET S4=S4/144.0
1205 PRINT USING 1210,H2,X1,P1,C1,S4
1210 :      ####.####     ####.####      ###.####     ###.####     ###.####
1215 NEXT J9
1220 GOTO 1530
1225 LET F2=A2*E(1)/(A2*E(2))
1230 LET F3=F2+1.0
1235 LET U1=H(1,11)-H(1,5)
1240 LET X1=P1*U1
1245 LET V1=-X1/F3
1250 LET B2=X1*F2/F3
1255 LET V2=X1/(2.0*F3)
1260 LET B3=-X1*F2/(2.0*F3)
1265 LET D5=SQR(E(2)↑2-E(1)↑2)
1270 LET H3=3.0*X1/(2.0*E(1)*F3)
1275 LET T4=ATN(D5/E(1))
1280 LET H4=H3*COS(T4)
1285 LET V3=3.0*X1/(2.0*D5)
1290 LET V4=-V3
1295 LET D6=E(1)/20.0
1300 LET D7=E(2)/20.0
1305 LET D8=-D6
1310 LET D9=-D7
1315 LET P4=C1/A1
1320 LET P5=C1/A1
1325 IF I4=1 THEN 1345
1330 PRINT TAB(31);"FAILED PILE"
1335 PRINT TAB(31);"_____ ____"
1340 GOTO 1355
1345 PRINT TAB(30);"REMAINING PILE"
1350 PRINT TAB(30);"_____ ____"
1355 PRINT
1360 PRINT USING 1137,M1
1365 PRINT USING 1141,N4
1370 PRINT USING 1145,J3
1375 PRINT USING 1149,J4
1380 PRINT USING 1153,P1
1385 PRINT
1390 PRINT
1391 PRINT TAB(30);"PILE 1(VERTICAL)"
1392 PRINT TAB(2);"DIST. FROM";TAB(34);"HOR.";TAB(48);"VER."
1396 PRINT TAB(1);"TOP OF PILE";TAB(20);"MOMENT";TAB(34);"SHEAR";TAB(48);
1398 PRINT "SHEAR";TAB(61);"STRESS"
```

000015

```
1402 PRINT TAB(20);"(FT*K)";TAB(35);"(K)";TAB(49);"(K)";TAB(60);"(K/IN**2)";
1410 FOR J9=1 TO 21 STEP 1
1415 LET D8=D8+D6
1420 LET D9=D9+D7
1425 LET G1=SQR(D9↑2-D8↑2)
1430 LET G2=D5-G1
1435 LET G3=E(1)-D8
1440 LET X2=G3/E(1)*U1+D8/E(1)*U2
1445 LET X(J9)=G1/D5*B3+G2/D5*B2
1450 LET S5=P4+X2*B1/A2
1455 LET Y(J9)=P5+X(J9)*B1/A2
1460 LET S5=S5/144.0
1465 LET Y(J9)=Y(J9)/144.0
1467 LET W(J9)=D8
1470 PRINT USING 1475,D8,X2,H3,V4,S5
1475 :   ###.##        ###.####        ###.####        ###.####        ###.####
1480 NEXT J9
1481 FOR J9=1 TO 2 STEP 1
1482 PRINT
1483 NEXT J9
1485 PRINT TAB(30);"PILE 2(BATTERED)"
1490 PRINT TAB(3);"DIST. FROM";TAB(34);"HOR.";TAB(48);"VER."
1495 PRINT TAB(2);"TOP OF PILE";TAB(20);"MOMENT";TAB(34);"SHEAR";TAB(48);
1500 PRINT "SHEAR";TAB(61);"STRESS"
1505 PRINT TAB(19);"(FT**K)";TAB(35);"(K)";TAB(49);"(K)";TAB(60);"(K/IN**2)"
1510 :   ###.##        ###.####        ###.####        ###.####        ###.####
1515 FOR J9=1 TO 21 STEP 1
1520 PRINT USING 1510,W(J9),X(J9),H4,V3,Y(J9)
1525 NEXT J9
1530 RETURN
8000 DISP "          END OF JOB"
9999 END

END OF LISTING



OLD *MAINL2
LIST
FILE    *MAINL2


0005 REM ****************************************************************************
0010 REM SUBROUTINE MAINL2(FROM DIAG TO INK=)
0015 REM ****************************************************************************
0020 FILES CO9;CO8;C1;COM1;P;N1;AC;AR;KLOOP
0025 DCL SINGLE
0027 DISP "          FRAME ANALYSIS"
0029 SETW :6 TO 1
0030 SETW :1 TO 1
0031 SETW :7 TO 1
0035 SETW :2 TO 1
0040 SETW :3 TO 1
0042 SETW :4 TO 1
0043 SETW :5 TO 1
0044 READ :5,U6,Z1,Z2,Z3
0045 REM -----------------------------------------------------
0046 REM READ FROM FILES
0047 REM -----------------------------------------------------
0048 FOR I9=1 TO 25 STEP 1
0049 FOR J9=1 TO 18 STEP 1
```

000016

```
0050 READ :8,L(I9,J9)
0051 NEXT J9
0052 NEXT I9
0053 FOR I9=1 TO 25 STEP 1
0054 READ :8,M(I9),T(I9),D(I9),V(I9),B(I9),F(I9),S(I9)
0055 NEXT I9
0056 IF U6=1 THEN 70
0057 READ :1,I,F(I),T(I),P1,A2
0067 READ :4,A(1)
0068 READ :5,F(I)
0069 GOTO 465
0070 READ :1,I,F(I),T(I),P1,A2,S1,V(I),N1,U1,D1,A4,A5
0071 READ :2,D4,D5,K3
0072 READ :6,K2
0073 READ :5,F(I)
0075 REM ------------------------------------------------------------------
0080 REM DIMENSIONING OF ARRAYS
0085 DIM F(25),S(25),T(25),V(25),L(25,18),M(25),D(25),R(40),A(20),B(25)
0090 REM ------------------------------------------------------------------
0455 REM ------------------------------------------------------------------
0460 REM REDIRECT PROGRAM FLOW TO START THIS SUBROUTINE AFTER FRAME
0465 IF U6=1 THEN 555
0470 REM ------------------------------------------------------------------
0475 REM
0480 REM
0485 REM ------------------------------------------------------------------
0490 REM MAINLINE MAINL2
0495 REM ------------------------------------------------------------------
0496 FOR I9=1 TO 40 STEP 1
0497 LET R(I9)=A(1)/12.0
0498 NEXT I9
0499 LET F1=F(I)
0500 LET K2=0
0501 GOTO 510
0502 LET F(I)=S(I)*D2
0505 LET F1=F(I)
0510 LET T1=T(I)
0515 LET A1=A2*3.14159265/180.0
0520 LET F2=F1*COS(P1)/SIN(A1)
0525 LET F1=F1*SIN(P1)/SIN(A1)
0530 REM ------------------------------------------------------------------
0535 REM CALL SUBROUTINE FRAME
0540 LET U6=1
0545 GOTO 4000
0550 REM ------------------------------------------------------------------
0555 LET U6=0
0560 LET S(I)=F(I)/D4
0565 LET O1=S(I)/S1
0570 LET O2=SQR(O1)
0575 LET D3=V(I)/O2
0580 LET A3=V(I)*O2
0585 LET F3=S(I)*V(I)/O2
0590 LET T2=3.14159265/(2.0*O2)
0595 LET H1=T2/N1
0600 LET H2=H1↑2/6.0
0605 LET H3=H1/2.0
0610 FOR J9=1 TO 6 STEP 1
0615 LET D2=D1+H1*U1+H2*(2.0*A4+A5)
0620 LET V2=U1+H3*(A4+A5)
0625 LET A5=-O1*D2
```

000017

```
0630 NEXT J9
0635 LET K1=K2+1
0640 LET L(I,K1)=K3
0645 LET M(I)=K1
0650 LET K2=K2+1
0655 IF K2>17 THEN 670
0660 LET T3=(D2-D4)/D2
0662 REM PRINT "TEST IN MAINL2 =",T3
0663 REM DISP USING 664,T3
0664   TEST IN MAINL2=###.########
0665 IF ABS(T3)-0.05>=0 THEN 502
0670 GOTO 675
0675 IF D5>=0.00001 THEN 685
0680 LET D5=D4
0685 LET S2=F(I)/D5
0690 LET O3=S2/S1
0695 LET O4=SQR(O3)
0700 LET X1=V(I)/O4
0705 LET X2=V(I)*O4
0710 LET X3=S2*V(I)/O4
0715 LET X4=3.14159265/(2.0*O4)
0720 LET F(I)=0.0
0721 GOTO 4000
0725 GOSUB 3015
0730 PRINT "DYNAMIC RESULTS FOR LINEAR SPRINGING"
0735 PRINT "_____ _____ ___ _____ _____"
0737 PRINT
0740 PRINT USING 745,X1
0745 : MAXIMUM DEFLECTION AT POINT OF IMPACT= ####.####   IN
0750 PRINT USING 755,X2
0755 : MAXIMUM SHIP ACCELERATION= ####.####   IN/SEC**2
0760 PRINT USING 765,X3
0765 : MAXIMUM SHIP FORCE=  ######.####   K
0770 PRINT USING 775,X4
0775 : STOPING TIME=  ####.####   SEC
0780 GOSUB 3015
0782 GOTO 4000
3000 REM ----------------------------------------------------
3005 REM PRINT SUBROUTINE
3010 REM ----------------------------------------------------
3015 FOR I9=1 TO 4 STEP 1
3020 PRINT
3025 NEXT I9
3030 RETURN
4000 SETW :8 TO 1
4001 FOR I9=1 TO 25 STEP 1
4002 FOR J9=1 TO 18 STEP 1
4004 WRITE :8,L(I9,J9)
4006 NEXT J9
4008 NEXT I9
4010 FOR I9=1 TO 25 STEP 1
4012 WRITE :8,M(I9),T(I9),D(I9),V(I9),B(I9),F(I9),S(I9)
4014 NEXT I9
4016 IF U6=0 THEN 4035
4018 SETW :5 TO 1
4020 SETW :6 TO 1
4022 WRITE :6,K2,F2,F1
4024 IF K2<>0 THEN 4032
4026 FOR I9=1 TO 40 STEP 1
4028 WRITE :6,R(I9)
4030 NEXT I9
```

```
4032 WRITE :5,U6,Z1,Z2,Z3,F(I)
4033 WRITE :9,I,K2
4034 CHAIN "*FRAME"
4035 WRITE :7,I,O1,A5,D2,H1,S(I),V1,H2,A4,H3,F(I),T(I),P1,A2,S1,D1
4037 WRITE :5,U6,Z1,Z2,Z3,F(I)
4038 WRITE :9,I,K2
4040 CHAIN "*MAINL3"
9999 END

END OF LISTING



FILE    *FRAME


0005 REM ***********************************************************************
0010 REM SUBROUTINE FRAME
0015 REM ***********************************************************************
0016 DCL SA1,SA2,SA3,SA4,SD1,SD2,SE1,SE2,SE3,SE4,SE5
0017 DCL SH1,SI1,SI2,SI3,SI5,SI6,SI7,SI4,SI8,SK1,SK2,SL1,SL2,SL3,SL(),SL4,SL5
0018 DCL SL7,SL8,SL9,SM,SM6,SM7,SM8,SM9,SN1,SN1,SN3,SN4,SN5,SN6,SN7,SN8,SN9,SN1
0019 DCL SM2,SM3,SM4,SM5,SP1,SP2,SR1,SR2,SR3,SR4,ST1,SV1,SL6
0020 FILES COMM9;COM1;COM2;COM3;COM4;COM8;COM9;CO3;CO5;C1;N1;ZP1;PO3;OO;OZ;AE;P
0025 SETW :1 TO 1
0035 REM --------------------------------------------------------------
0040 REM READ FROM FILES
0045 REM --------------------------------------------------------------
0047 READ :1,I
0050 READ :1,C(I),D5,A(I),A6,P1,L1,L3,N3,N5,L6,I5,I6,E3,H1,E4
0055 READ :1,R1,A1,N3,H1,E4
0057 IF I5=0 THEN 60
0058 READ :1,A2,R2,E5
0060 FOR I9=1 TO 30 STEP 1
0065 READ :1,L(I9)
0066 NEXT I9
0073 READ :11,K1,F3,F2
0076 REM IF L1<>1 THEN 81
0077 REM IF K1<>0 THEN 81
0078 FOR I9=1 TO 40 STEP 1
0079 READ :11,S(I9)
0080 NEXT I9
0081 SETW :12 TO 1
0085 READ :12,E3
0088 SETW :16 TO 1
0089 SETW :17 TO 1
0090 READ :17,U6,N1,N4,I4,W8
0092 IF U6<>2 THEN 326
0094 READ :16,F2,F3,K1,L1
0096 REM PRINT "K1=";K1
0097 IF L1=1 THEN 326
0098 FILE : 16,"P2"
0099 FOR I9=1 TO 30 STEP 1                        000019
0100 READ :16,L(I9)
0101 NEXT I9
0103 REM --------------------------------------------------------------
0105 REM DIMENSIONING OF ARRAYS
0110 DIM E(20),L(30),T(40),F(192),S(40),D(192),R(82)
0115 REM --------------------------------------------------------------
0326 IF L1<>1 THEN 328
```

```
0327 IF K1=0 THEN 330
0328 SETW :13 TO 3
0329 READ :13,I4
0330 LET D2=0
0332 LET D1=0
0333 IF L1<>1 THEN 365
0334 IF K1<>0 THEN 365
0335 FOR I9=1 TO 40 STEP 1
0340 LET T(I9)=0.0
0345 NEXT I9
0350 FOR I9=1 TO 192 STEP 1
0355 LET F(I9)=0.0
0360 LET D(I9)=0.0
0364 NEXT I9
0365 IF L1>=2 THEN 367
0366 IF K1=0 THEN 380
0367 SETW :15 TO 1
0368 READ :15,Z9,Z8,L3
0369 FOR I9=1 TO Z9 STEP 1
0370 READ :15,S(I9)
0371 NEXT I9
0372 FOR I9=1 TO 20 STEP 1
0373 LET E(I9)=0.0
0374 NEXT I9
0375 FOR I9=1 TO Z8 STEP 1
0376 READ :15,E(I9)
0377 NEXT I9
0380 LET L1=INT(L1)
0382 LET L3=INT(L3)
0384 LET N3=INT(N3)
0386 LET N5=INT(N5)
0388 LET L6=INT(L6)
0390 LET I5=INT(I5)
0392 LET I6=INT(I6)
0394 LET N3=INT(N3)
0396 LET K1=INT(K1)
0399 IF L1<>1 THEN 401
0400 IF K1=0 THEN 485
0401 FILE : 12,"P7"
0402 SETW :12 TO 1
0403 READ :12,L6
0404 IF K1<>0 THEN 485
0405 IF L1<>L6 THEN 414
0406 READ :12,M9
0407 FOR I9=1 TO M9 STEP 1
0408 READ :12,F(I9)
0409 NEXT I9
0410 FOR I9=1 TO 40 STEP 1
0411 READ :12,T(I9)
0412 NEXT I9
0413 GOTO 485
0414 FILE : 11,"OY"
0415 SETW :11 TO 1
0416 READ :11,W7
0417 FOR I9=1 TO W7 STEP 1
0418 READ :11,D(I9)
0419 NEXT I9
0485 REM ------------------------------------------------
0487 REM SUBROUTINE FRAME MAINLINE
0488 REM ------------------------------------------------
0489 REM IF L1>=2 THEN 492
0490 REM SUBROUTINE FRAME MAINLINE
```

```
0491 REM IF K1=0 THEN 500
0492 REM PRINT USING 493,F3,P1,F2,L3
0493 : FORCEH= ####.####   PHI= ##.####   FORCE= ####.#### LDPT= ###
0494 FOR I9=1 TO 15 STEP 1
0495 REM PRINT USING 496,E[I9],S[I9]
0496 : DELTA= ####.####    SPRNGK= ####.####
0497 NEXT I9
0498 REM DISP USING 499,F2,L1,K1,L6
0499 :FRAME FRCE= ###.##### I=### KOUNT=### LVOLD=###
0500 IF ABS(P1)>=1E-7 THEN 510
0505 LET F1=F3/COS(P1)
0510 IF ABS(P1)<1E-7 THEN 520
0515 LET F1=F2/SIN(P1)
0520 LET F2=F1
0525 LET F3=F1
0530 IF N1=0 THEN 560
0535 IF N1>0 THEN 550
0540 LET T1=3.14159265/4.0
0545 GOTO 565
0550 LET T1=-3.14159265/4.0
0555 GOTO 565
0560 LET T1=0.0
0565 LET P2=P1+T1
0570 LET F2=F2*SIN(P2)
0575 LET F3=F3*COS(P2)
0580 LET I1=0.0
0585 IF L1<>1 THEN 597
0590 IF K1<>0 THEN 597
0595 LET L2=L3
0596 GOTO 600
0597 LET L2=0.0
0600 IF L1=1 THEN 650
0605 LET N2=N3
0610 IF N4<1 THEN 620
0615 LET N2=N5-N4*INT(N5/(N4+1))
0620 LET I2=0.0
0622 LET N3=INT(N3)
0625 FOR I3=1 TO N3 STEP 1
0630 IF L[I3]<>0 THEN 640
0635 LET I2=I2+1
0640 NEXT I3
0645 IF I2=N2 THEN 1635
0650 GOTO 655
0655 IF L1=1 THEN 750
0660 LET L4=INT((I4-2)/3)
0665 LET I2=0.0
0670 LET N6=INT((L4+N4)/(N4+1))
0680 FOR I3=1 TO L4 STEP 1
0685 IF L[I3]<>0 THEN 695
0690 LET I2=I2+1
0695 NEXT I3
0700 IF I2=N6 THEN 1675
0705 LET I2=0.0
0710 LET L5=N5-L4+1
0715 LET N6=INT((L5+N4)/(N4+1))
0720 LET N5=INT(N5)
0722 LET L4=INT(L4)
0725 FOR I3=L4 TO N5 STEP 1
0730 IF L[I3]<>0 THEN 740
0735 LET I2=I2+1
0740 NEXT I3
```

000021

```
0745 IF I2=N6 THEN 1675
0750 GOTO 755
0755 IF L1<>1 THEN 780
0760 IF K1<>0 THEN 780
0765 FOR I9=1 TO 20 STEP 1
0770 LET E(I9)=0.0
0775 NEXT I9
0780 GOTO 785
0785 IF K1<>0 THEN 830
0790 IF L1<>L6 THEN 830
0795 FOR L7=1 TO 40 STEP 1
0800 LET S(L7)=T(L7)
0805 NEXT L7
0806 FILE : 11,"OY"
0807 SETW :11 TO 1
0808 WRITE :11,M9
0810 FOR L7=1 TO M9 STEP 1
0815 LET D(L7)=F(L7)
0817 WRITE :11,D(L7)
0820 NEXT L7
0825 LET D1=D2
0830 IF K1<>0 THEN 880
0835 IF L1=L6 THEN 880
0840 FOR L7=1 TO 40 STEP 1
0845 LET T(L7)=S(L7)
0850 NEXT L7
0851 LET M9=3*(3*N5+4)
0852 IF L1=1 THEN 855
0853 LET M9=W7
0855 FOR L7=1 TO M9 STEP 1
0860 LET F(L7)=D(L7)
0865 NEXT L7
0870 LET D2=D1
0875 LET L6=L1
0880 LET E1=1000.0
0885 IF L1<>1 THEN 900
0890 IF K1<>0 THEN 900
0892 SETW :3 TO 1
0895 WRITE :3,I5,I6,L3
0900 IF L1=1 THEN 910
0902 SETW :3 TO 1
0905 READ :3,I5,I6,L3
0910 IF K1=0 THEN 915
0912 SETW :3 TO 1
0915 IF I5=0 THEN 1105
0920 IF L1<>1 THEN 935
0925 IF K1<>0 THEN 935
0930 LET E2=E3/144.0
0935 IF L1=1 THEN 945
0937 SETW :4 TO 1
0940 READ :4,N3,N5
0945 IF K1=0 THEN 955
0947 SETW :4 TO 1
0950 READ :4,N3,N5
0955 LET N4=INT((N5-N3)/(N3-1))
0960 IF N4=0 THEN 1065
0965 LET N7=0
0970 LET N8=N4+1
0975 LET I7=5
0980 LET K2=0
0985 IF L2=I7 THEN 1055
```

```
0990 LET N9=N5-1
0995 LET N9=INT(N9)
1000 FOR I9=1 TO N9 STEP 1
1005 LET K2=K2+1
1010 LET I7=I7+2
1015 IF K2<>N8 THEN 1025
1020 LET I7=I7+1
1025 IF K2=N8 THEN 1035
1030 LET N7=N7+1
1035 IF K2<>N8 THEN 1045
1040 LET K2=0
1045 IF L3=I7 THEN 1055
1050 NEXT I9
1055 GOTO 1060
1060 LET L3=L2+N7
1065 GOTO 1070
1070 IF L2<>0 THEN 1080
1075 LET L3=INT((N5+1)/2)*3+2
1080 LET M1=N5-INT(N5/2)*2
1085 IF M1<>0 THEN 1095
1090 LET L3=L3+3
1095 LET I4=L3
1100 GOTO 1230
1105 IF L1<>1 THEN 1120
1110 IF K1<>0 THEN 1120
1115 LET E2=E3/144.0
1120 LET L3=INT((L3+1)*3/2)-1
1125 IF L2<>0 THEN 1135
1130 LET L3=INT((N3+1)/2)*3+2
1135 LET M1=N3-INT(N3/2)*2
1140 IF M1<>0 THEN 1150
1145 LET L3=L3+3
1150 LET I4=L3
1155 IF L1<>1 THEN 1170
1160 IF K1<>0 THEN 1170
1162 SETW :3 TO 3
1165 WRITE :3,N3,H1,E4,E2,R1,A1
1170 IF L1=1 THEN 1180
1172 SETW :3 TO 3
1175 READ :3,N3,H1,E4,E2,R1,A1
1180 IF K1=0 THEN 1190
1182 SETW :3 TO 3
1185 READ :3,N3,H1,E4,E2,R1,A1
1190 LET N5=N3
1195 LET E5=E4
1200 LET E4=100.0
1205 LET E1=E2
1210 LET R2=R1
1215 LET R1=10.0
1220 LET A2=A1
1225 LET A1=1.0
1230 IF L1<>1 THEN 1245
1235 IF K1<>0 THEN 1245
1237 SETW :4 TO 1
1240 WRITE :4,N3,N5,H1,E5,E4,E2,E1,R2,R1,A2,A1
1245 IF L1=1 THEN 1255
1247 SETW :4 TO 1
1250 READ :4,N3,N5,H1,E5,E4,E2,E1,R2,R1,A2,A1
1255 IF K1=0 THEN 1265
1257 SETW :4 TO 1
1260 READ :4,N3,N5,H1,E5,E4,E2,E1,R2,R1,A2,A1
```

```
1265 LET F4=F2
1270 LET L8=L3
1275 LET F2=0.0
1280 LET L9=L8+3
1285 GOTO 1290
1290 REM M4= THE NUMBER OF SPRINGS WHICH HAVE A K VALUE OF
1295 REM ZERO BETWEEN TWO CONSECUTIVE SUPPORT SPRINGS
1300 LET M4=INT((N5-N3)/(N3-1))
1305 LET M2=N3
1310 IF L1<>1 THEN 1370
1315 IF K1<>0 THEN 1370
1320 LET M3=N3
1325 LET M4=N5
1330 LET N3=INT(N3)
1335 FOR I9=1 TO N3 STEP 1
1340 LET M4=INT(M4)
1345 LET M3=INT(M3)
1350 LET S(M4)=S(M3)
1355 LET M4=M4-(M4+1)
1360 LET M3=M3-1
1365 NEXT I9
1370 LET N3=N5
1375 LET V1=20
1380 LET R3=0.00001
1385 LET R4=0.00001
1390 LET A3=1.0
1395 LET A4=1.0
1400 LET N3=INT(N3)
1402 SETW :5 TO 1
1405 FOR I9=1 TO N3 STEP 1
1410 WRITE :5,S(I9)
1415 NEXT I9
1420 LET I8=15
1425 LET M=2*N3+1+(2*N5+1)
1430 LET M5=3*N3+4
1435 LET M6=N3
1440 LET M7=2*M6
1445 LET M8=3*M5-M7
1450 REM
1455 REM
1460 REM B JOINT COORDINATES
1465 REM B
1470 LET M9=M5*3
1475 LET N3=INT(N3)
1480 FOR I9=1 TO N3 STEP 1
1485 IF L1<>1 THEN 1500
1490 IF K1<>0 THEN 1500
1495 LET R(I9)=S(I9)
1500 NEXT I9
1505 REM -----------------------------
1510 REM CALL SUBROUTINE MAIN
1520 GOTO 3000
1525 REM -----------------------------
1635 FOR I9=1 TO 3 STEP 1
1640 PRINT
1645 NEXT I9
1650 PRINT "    ****************************************************************"
1655 PRINT "    *           ALL PILES IN THE SYSTEM HAVE FAILED              *"
1660 PRINT "    ****************************************************************"
1665 LET I1=1
1670 GOTO 1710
```

```
1675 FOR I9=1 TO 3 STEP 1
1680 PRINT
1685 NEXT I9
1690 PRINT "     **********************************************************************"
1695 PRINT "     *  ALL PILES EFFECTIVE DUE TO ASYMMETRIC LOADING HAVE FAILED  *"
1700 PRINT "     **********************************************************************"
1705 LET I1=1
1710 REM
2000 REM ------------------------------------------------------------------
2005 REM WRITE INTO FILES
2010 REM ------------------------------------------------------------------
3000 IF I1=1 THEN 3005
3001 SETW :2 TO 2
3002 WRITE :2,I6,L1,K1,I5,N4,M5,N5,P1,N1,A4,A3,A1,A2,R2,R1,R4,R3
3003 WRITE :2,E1,E5,E4,E2,H1,V1,F3,F4,L8,L9,M9,F4,N3,M,I1
3005 FILE : 3,"ZZ5"
3006 SETW :3 TO 1
3007 WRITE :3,I1,N4,N5,N3
3012 IF I1<>1 THEN 3015
3013 CHAIN "*MAINL3"
3015 SETW :6 TO 7
3020 WRITE :6,I8,M8,L1
3025 SETW :7 TO 1
3030 FOR I9=1 TO 20 STEP 1
3035 WRITE :7,E(I9)
3036 NEXT I9
3037 FOR I9=1 TO 30 STEP 1
3038 WRITE :7,L(I9)
3039 NEXT I9
3041 IF L1<>1 THEN 3046
3042 IF K1<>0 THEN 3046
3043 FOR I9=1 TO N3 STEP 1
3044 WRITE :7,R(I9)
3045 NEXT I9
3046 SETW :8 TO 1
3050 FOR I9=1 TO 40 STEP 1
3055 WRITE :8,S(I9)
3060 NEXT I9
3065 WRITE :8,E3
3070 SETW :9 TO 1
3075 WRITE :9,M2,L3
3080 SETW :10 TO 1
3085 WRITE :10,K1
3090 SETW :13 TO 2
3094 WRITE :13,L1,I4
3095 IF L1<>1 THEN 4000
3096 IF K1<>0 THEN 4000
3097 FOR I9=1 TO N3 STEP 1
3098 WRITE :14,R(I9)
3099 NEXT I9
4000 SETW :17 TO 1
4001 WRITE :17,U6,N1,N4,I4,W8
4002 IF K1<>0 THEN 4012
4003 FILE : 12,"P7"
4004 SETW :12 TO 1
4005 WRITE :12,L6,M9
4006 FOR I9=1 TO M9 STEP 1
4007 WRITE :12,F(I9)
4008 NEXT I9
4009 FOR I9=1 TO 40 STEP 1
4010 WRITE :12,T(I9)
```

```
4011 NEXT I9
4012 REM ------------------------------------------------------------
4013 CHAIN "*IMPT1"
4015 REM ------------------------------------------------------------
5000 END

END OF LISTING


OLD *MAINL3
LIST
FILE    *MAINL3


0005 REM **********************************************************************
0010 REM SUBROUTINE MAINL2(FROM LINE NO. 306 TO SECOND CALL FRAME)
0015 REM **********************************************************************
0020 FILES P
0025 DCL SINGLE
0080 REM ------------------------------------------------------------
0085 REM READ FROM FILES
0088 REM ------------------------------------------------------------
0090 SETW :1 TO 1
0091 READ :1,U6,X(6),X(7),X(8),X(9)
0092 FILE : 1,"AR"
0093 SETW :1 TO 1
0094 FOR I9=1 TO 25 STEP 1
0095 FOR J9=1 TO 18 STEP 1
0096 READ :1,L(I9,J9)
0097 NEXT J9
0098 NEXT I9
0099 FOR I9=1 TO 25 STEP 1
0100 READ :1,M(I9),T(I9),E(I9),V(I9),A(I9),F(I9),S(I9)
0101 NEXT I9
0102 FILE : 1,"ZZ5"
0103 SETW :1 TO 1
0105 READ :1,I4,N2,N3,N1
0111 FILE : 1,"AA"
0112 SETW :1 TO 1
0115 READ :1,I3,I7,G3,M3,Y1,G6
0120 FOR I9=1 TO 30 STEP 1
0125 READ :1,O(I9),N(I9)
0130 NEXT I9
0131 FILE : 1,"AB"
0132 SETW :1 TO 1
0135 READ :1,N5,G9,G8
0137 FILE : 1,"AC"
0138 SETW :1 TO 1
0140 READ :1,I,O1,A5,D2,H1,S(I),V1,H2,A4,H3,F(I),T(I),P1,A2,S1,D1
0141 FILE : 1,"AD"
0142 SETW :1 TO 1
0145 READ :1,P3,A6,A7,Z(10),Z(9),K
0146 FOR I9=1 TO K STEP 1
0147 READ :1,G(I9)
0148 NEXT I9
0150 FOR I9=1 TO 10 STEP 1
0155 FOR J9=1 TO 60 STEP 1
0160 READ :1,H(I9,J9)
0165 NEXT J9
0170 NEXT I9
```

```
0171 FILE : 1,"C08"
0172 SETW :1 TO 1
0175 READ :1,D3,Y(1),K3
0176 FILE : 1,"OZ"
0177 SETW :1 TO 1
0180 READ :1,Y(2),Y(1),Y(1)
0185 FOR I9=1 TO Y(2) STEP 1
0190 READ :1,R(I9)
0195 NEXT I9
0196 FILE : 1,"OY"
0197 SETW :1 TO 1
0198 READ :1,B(1)
0200 FOR I9=1 TO B(1) STEP 1
0205 READ :1,D(I9)
0210 NEXT I9
0215 IF U6<>2 THEN 225
0217 FILE : 1,"AE"
0218 SETW :1 TO 1
0220 READ :1,F1,F2,K2,I,A5,F(I),I1,S4,S5,S6,T1,I3,T4,I2,T(I)
0222 READ :1,D1,V1,A4
0225 REM
0230 REM
0235 REM --------------------------------------------------------------
0240 REM DIMENSIONING OF ARRAYS
0245 DIM F(50),S(50),T(50),V(50),L(50,36),M(50),D(120),N(120),R(120),O(120)
0250 DIM H(10,60),Q(50),E(50),A(50),W(63)
0255 REM --------------------------------------------------------------
0260 REM
0265 REM
0455 REM --------------------------------------------------------------
0460 REM REDIRECT PROGRAM FLOW TO START THIS SUBROUTINE AFTER FRAME
0465 IF U6=2 THEN 980
0470 REM --------------------------------------------------------------
0475 REM
0480 REM
0785 LET I1=N2+1
0790 LET I2=1
0795 LET I=I+1
0800 IF I3<>2 THEN 835
0805 IF I=I2 THEN 835
0810 IF I<=2 THEN 835
0815 REM --------------------------------------------------------------
0820 REM CALL SUBROUTINE JNTDP
0825 GOSUB 2006
0830 REM --------------------------------------------------------------
0835 IF I=I2 THEN 865
0840 IF I<=2 THEN 865
0845 REM --------------------------------------------------------------
0850 REM CALL SUBROUTINE CHART
0855 GOSUB 2515
0860 REM --------------------------------------------------------------
0865 LET I2=I
0870 LET S4=01
0875 LET S5=A5
0880 LET S6=D2
0885 LET T(I)=(I-1)*H1
0890 LET S(I)=S(I-1)
0895 FOR J9=1 TO 6 STEP 1
0900 LET D2=D1+H1*V1+H2*(2.0*A4+A5)
0905 LET V2=V1+H3*(A4+A5)
```

000027

```
0910 LET A5=-01*D2
0915 NEXT J9
0920 LET K2=0
0925 LET F(I)=S(I)*D2
0930 LET F1=F(I)
0935 LET T1=T(I)
0940 LET T4=T1
0942 LET A1=A2*3.14159265/180.0
0945 LET F2=F1*COS(P1)/SIN(A1)
0950 LET F1=F1*SIN(P1)/SIN(A1)
0955 REM -------------------------------------------------------
0960 REM CALL SUBROUTINE FRAME
0965 LET U6=2
0970 GOTO 4000
0975 REM -------------------------------------------------------
0980 LET U6=0
0985 IF I4=1 THEN 4000
0990 LET S(I)=F(I)/D3
0995 LET 01=S(I)/S1
1000 FOR J9=1 TO 6 STEP 1
1005 LET D2=D1+H1*V1+H2*(2.0*A4+A5)
1010 LET V2=V1+H3*(A4+A5)
1015 LET A5=-01*D2
1020 NEXT J9
1025 LET K1=K2+1
1030 LET L(I,K1)=K3
1035 LET M(I)=K1
1040 LET K2=K2+1
1045 IF K2>17 THEN 1060
1050 LET T2=(D2-D3)/D2
1055 IF ABS(T2)-0.05>=0 THEN 925
1060 LET I5=3-3*I1
1065 LET L1=0
1070 LET N1=INT(N1)
1075 LET I1=INT(I1)
1080 FOR I9=1 TO N1 STEP I1
1085 LET I5=I5+3*I1
1090 IF N(I9)=0 THEN 1305
1095 IF O(I9)=1 THEN 1305
1100 LET I6=I5+1
1105 LET J1=I5*3
1110 LET J2=I6*3
1115 LET D4=(D(J2-1)-D(J1-1))↑2
1120 LET D5=(D(J2-2)-D(J1-2))↑2
1125 LET D6=SQR(D5+D4)
1130 IF I7<>0 THEN 1140
1135 LET D6=D6*2.0
1140 LET P2=D6*R(I9)
1145 IF I7<>0 THEN 1155
1150 LET P2=P2/2.0
1155 IF P2-P3<=0 THEN 1305
1160 LET N(I9)=0
1165 LET Q(I9)=P3/D6
1170 IF I7<>0 THEN 1180
1175 LET Q(I9)=Q(I9)*2.0
1180 LET S3=R(I)
1185 IF I7<>0 THEN 1195
1190 LET S3=S3/2.0
1195 LET D7=D6
1200 LET M1=INT(M3*3+2+I9)
1205 LET N4=INT((I9+(I1-1))/I1)
```

```
1210 LET J3=I5
1215 LET J4=I6
1220 IF I7<>0 THEN 1250
1225 LET N4=INT(M1-(3*N3+2))
1230 LET M1=INT(N4+(N3+1))
1235 LET J3=2*N4
1240 LET J4=J3+1
1245 GOTO 1275
1250 IF I7<>1 THEN 1275
1255 IF N2=0 THEN 1275
1260 LET M1=INT(N4+(3*N3+2))
1265 LET J3=INT(5+(N4-1)*(2*N2+3)-2)
1270 LET J4=J3+1
1275 GOTO 1276
1276 FOR K9=1 TO 5 STEP 1
1277 PRINT
1278 NEXT K9
1280 REM ------------------------------------------------------
1285 REM CALL SUBROUTINE PLA
1290 GOSUB 3500
1295 REM ------------------------------------------------------
1300 LET L1=L1+1
1305 NEXT I9
1310 IF L1=0 THEN 1360
1315 FOR I9=1 TO 36 STEP 1
1320 LET L(I,I9)=0
1325 NEXT I9
1330 LET M(I)=0
1335 LET I=I-1
1340 LET O1=S4
1345 LET A5=S5
1350 LET D2=S6
1355 GOTO 795
1360 LET E(I)=D2
1365 LET V(I)=V2
1370 LET A(I)=A5
1375 LET F(I)=S(I)*D2
1380 LET D8=D2-D1
1385 LET D1=D2
1390 LET V1=V2
1395 LET A4=A5
1400 IF D8>=0 THEN 795
1405 LET I5=INT(3-3*I1)
1410 LET T4=T1
1415 IF I3<>2 THEN 1435
1420 REM ------------------------------------------------------
1425 REM CALL SUBROUTINE JNTDP
1430 GOSUB 2006
1435 REM ------------------------------------------------------
1440 REM
1445 REM ------------------------------------------------------
1450 REM CALL SUBROUTINE CHART                    000029
1455 GOSUB 2515
1460 REM ------------------------------------------------------
1465 GOTO 4000
1970 REM ==================================================================
1975 REM SUBROUTINES
1980 REM ==================================================================
1985 REM
1990 REM
1995 REM ------------------------------------------------------
```

```
2000 REM JNTDP
2005 REM --------------------------------------------------------
2006 LET N8=3*N5+4
2007 FOR I9=1 TO 6 STEP 1
2008 PRINT
2009 NEXT I9
2010 PRINT "                              JOINT DISPLACEMENTS"
2015 PRINT "                              ----- -------------"
2020 PRINT
2025 PRINT TAB(3);"JOINT";TAB(23);"X";TAB(44);"Y";TAB(64);"Z"
2030 PRINT TAB(3);"NUMBER";TAB(18);"DISPLACEMENT";TAB(39);"DISPLACEMENT";
2031 PRINT TAB(61);"ROTATION"
2035 PRINT TAB(22);"(IN)";TAB(43);"(IN)";TAB(63);"(RAD)"
2045 IF G9=0 THEN 2155
2050 LET I9=0
2055 LET J9=0
2060 LET J5=N8-1
2065 LET N8=INT(N8)
2070 FOR K9=1 TO N8 STEP 1
2075 LET I9=I9+1
2080 IF I9>=J5 THEN 2120
2085 LET J6=I9-INT(I9/3)*3
2090 IF J6<>0 THEN 2120
2095 LET J6=INT(I9/3)
2100 LET J6=J6-1
2105 LET J6=J6-INT(J6/(G8+1))*(G8+1)
2110 IF J6=0 THEN 2120
2115 GOTO 2145
2120 LET J9=J9+1
2125 LET I8=3*I9-2
2130 LET G1=3*I9-1
2135 LET G2=3*I9
2140 PRINT USING 2142,J9,D(I8),D(G1),D(G2)
2142 :    ###           #######.####        #######.####        #####.####
2145 NEXT K9
2150 GOTO 2240
2155 LET I9=0
2160 LET J9=0
2165 LET J5=N8-1
2170 FOR K9=1 TO N8 STEP 1
2175 LET I9=I9+1
2180 IF I9=J5 THEN 2235
2185 IF I9=N8 THEN 2205
2190 LET J6=I9-1
2195 LET J6=J6-INT(J6/3)*3
2200 IF J6=0 THEN 2235
2205 LET J9=J9+1
2210 LET I8=3*I9-2
2215 LET G1=3*I9-1
2220 LET G2=3*I9
2225 PRINT USING 2230,J9,D(I8),D(G1),D(G2)
2230 :    ###           #######.####        #######.####        *####.####
2235 NEXT K9
2240 RETURN
2500 REM --------------------------------------------------------
2505 REM SUBROUTINE CHART
2510 REM --------------------------------------------------------
2515 FOR I9=1 TO 6 STEP 1
2516 PRINT
2517 NEXT I9
2518 IF I7=0 THEN 2605
```

```
2520 IF G3<>1 THEN 2565
2525 PRINT USING 2530,T4
2530 :                   FENDER AND PILE DEFORMATIONS AT TIME= ###.#### SECONDS
2535 PRINT "                 ------ --- ---- ------------ -- ------------- -------"
2540 PRINT
2542 PRINT
2545 PRINT TAB(8);"SPRING";TAB(27);"PILE";TAB(43);"SPRING";TAB(60);"FENDER"
2550 PRINT TAB(8);"NUMBER";TAB(24);"DEFLECTION";TAB(43);"NUMBER";TAB(59);
2551 PRINT "DEFLECTION"
2555 PRINT TAB(27);"(IN)";TAB(62);"(IN)"
2565 IF G3<>2 THEN 2600
2570 PRINT USING 2575,T4
2575 :    FENDER AND PILE DEFORM. AND SPRING CONST. AT TIME=##.##### SECONDS
2580 PRINT "   ------ --- ---- ------- --- ------ ------ -- --------------- --";
2581 PRINT "_____"
2582 PRINT
2585 PRINT TAB(3);"SPRING";TAB(14);"PILE";TAB(24);"SPRING";TAB(41);"SPRING";
2586 PRINT TAB(50);"FENDER";TAB(62);"SPRING"
2590 PRINT TAB(3);"NUMBER";TAB(11);"DEFLECTION";TAB(23);"CONSTANT";TAB(41);
2591 PRINT "NUMBER";TAB(49);"DEFLECTION";TAB(61);"CONSTANT"
2595 PRINT TAB(14);"(IN)";TAB(24);"(K/IN)";TAB(52);"(IN)";TAB(62);"(K/IN)"
2600 GOTO 2690
2605 IF G3<>1 THEN 2650
2610 PRINT USING 2615,T4
2615 :                    PILE DEFORMATION AT TIME= ###.##### SECONDS
2620 PRINT "                 ---- ----------- -- --------------- -------"
2625 PRINT
2630 PRINT TAB(26);"SPRING";TAB(46);"PILE"
2635 PRINT TAB(26);"NUMBER";TAB(43);"DEFLECTION"
2640 PRINT TAB(46);"(IN)"
2645 PRINT
2650 IF G3<>2 THEN 2690
2655 PRINT USING 2660,T4
2660 :          PILE DEFORMATIONS AND SPRING CONSTANTS AT TIME=  ###.##### SECONDS
2665 PRINT "          ---- ------------ --- ------ --------- -- ----------------";
2666 PRINT " _____"
2670 PRINT
2675 PRINT TAB(22);"SPRING";TAB(38);"PILE";TAB(49);"SPRING"
2680 PRINT TAB(22);"NUMBER";TAB(35);"DEFLECTION";TAB(48);"CONSTANT"
2685 PRINT TAB(38);"(IN)";TAB(49);"(K/IN)"
2690 LET J7=0
2695 LET K4=1
2700 LET L2=2
2705 LET M2=0
2710 LET N9=INT(M3/(M2+1))+1
2715 IF M2<>0 THEN 2725
2720 LET N9=M3
2725 LET M3=INT(M3)
2730 FOR I9=1 TO M3 STEP 1
2735 LET J7=J7+3
2740 LET K4=K4+3
2745 LET L2=L2+3
2750 LET J8=3*J7-2
2755 LET W1=3*J7-1
2760 LET K5=3*K4-2
2765 LET K6=3*K4-1
2770 LET L3=3*L2-2
2775 LET L4=3*L2-1
2780 LET C1=SQR((D(K5)-D(J8))^2+(D(K6)-D(W1))^2)
2785 LET C2=SQR((D(L3)-D(K5))^2+(D(L4)-D(K6))^2)
```

000031

```
2790 IF C2<=M3 THEN 2810
2795 IF M3<=1E-3 THEN 2810
2800 IF I7<>1 THEN 2810
2805 LET C2=M3
2810 LET G4=INT((I9-1)/(M2+1))*(M2+1)
2815 LET G5=I9-1
2820 IF G4<>G5 THEN 2830
2825 LET M2=M2+1
2830 LET N9=N9+1
2835 IF I7=0 THEN 2950
2840 IF G3<>1 THEN 2860
2845 IF G4<>G5 THEN 2860
2850 PRINT USING 2855,M2,C1,N9,C2
2855 :        ###                   ####.##            ###                   ####.##
2860 IF G3<>2 THEN 2878
2865 IF G4<>G5 THEN 2878
2870 IF N(I9)=0 THEN 2878
2875 PRINT USING 2877,M2,C1,R(I9),N9,C2,R(I9+N3)
2877 :    ###    #######.## #####.##              ###    #######.## #####.##
2878 IF N(I9)<>0 THEN 2880
2879 LET F9=P3/C1
2880 IF G3<>2 THEN 2905
2885 IF G4<>G5 THEN 2905
2890 IF N(I9)<>0 THEN 2905
2895 PRINT USING 2900,M2,C1,F9,N9,C2,R(I9+N3)
2900 :    ###    #######.## #####.##              ###    #######.## #####.##
2905 IF G3<>1 THEN 2925
2910 IF G4=G5 THEN 2925
2915 PRINT USING 2920,N9,C2
2920 :                                  ###                   ####.##
2925 IF G3<>2 THEN 2945
2930 IF G4=G5 THEN 2945
2935 PRINT USING 2940,N9,C2,R(I9+N3)
2940 :                                  ###    #######.## #####.##
2945 GOTO 3000
2950 LET C3=C1+C2
2955 LET S2=R(I9)/2.0
2960 IF N(I9)<>0 THEN 2970
2965 LET S2=P3/C3
2970 IF G3<>1 THEN 2985
2975 PRINT USING 2980,M2,C3
2980 :                        ###                ###.###
2985 IF G3<>2 THEN 3000
2990 PRINT USING 2995,M2,C3,S2
2995 :                        ###             ###.###     ###.###
3000 NEXT I9
3005 RETURN
3485 REM ------------------------------------------------------------
3490 REM SUBROUTINE PLA
3495 REM ------------------------------------------------------------
3500 IF G6=1 THEN 3515
3505 LET P4=P3
3510 GOTO 3520
3515 LET P4=S3*D7
3520 ON Y1 GOTO 3525,3675                               000032
3525 LET K7=1
3530 LET P4=P4/K
3535 LET H4=G(K7)/20.0
3540 LET H5=-H4
3545 LET T5=P4*H(K7,K7*6+5)
3550 LET P5=Z(10)/A6
```

```
3555 IF G6=1 THEN 3575
3560 PRINT TAB(34);"FAILED PILES"
3565 PRINT TAB(34);"_____ _____"
3570 GOTO 3585
3575 PRINT TAB(34);"REMAINING PILES"
3580 PRINT TAB(34);"_____ _____"
3585 PRINT
3587 PRINT USING 3590,M1
3590 :      MEMBER NUMBER      ####
3592 PRINT USING 3595,N4
3595 :      SPRING NUMBER      ####
3597 PRINT USING 3600,J3
3600 :      STARTING JOINT     ####
3602 PRINT USING 3605,J4
3605 :      ENDING JOINT       ####
3607 PRINT USING 3610,P4
3610 :      FORCE              ####.####   K
3612 PRINT
3615 PRINT TAB(5);" DISTANCE FROM";TAB(35);"HORIZONTAL";TAB(51);"VERTICAL"
3620 PRINT TAB(6);"TOP OF PILE";TAB(23);"MOMENT";TAB(37);"SHEAR";TAB(52);
3621 PRINT "SHEAR";TAB(66);"STRESS"
3625 PRINT TAB(8);"(FT)";TAB(23);"(FT*K)";TAB(38);"(K)";TAB(53);"(K)";TAB(64);
3626 PRINT "(K/IN**2)"
3630 FOR K9=1 TO 21 STEP 1
3635 LET H5=H5+H4
3640 LET X1=T5+P4*H5
3645 LET S7=P5+X1*Z(9)/A7
3650 LET S7=S7/144.0
3655 PRINT USING 3660,H5,X1,P4,Z(10),S7
3660 :      ####.####   #####.####     ####.####      ####.####     ####.####
3665 NEXT K9
3670 GOTO 3985
3675 LET F4=A7*G(1)/(A7*G(2))
3680 LET F5=F4+1.0
3685 LET U1=H(1,11)-H(1,5)
3690 LET X1=P4*U1
3695 LET V3=-X1/F5
3700 LET B1=X1*F4/F5
3705 LET V4=X1/(2.0*F5)
3710 LET B2=-X1*F4/(2.0*F5)
3715 LET E1=SQR(G(2)↑2-G(1)↑2)
3720 LET H6=3.0*X1/(2.0*G(1)*F5)
3725 LET T6=ATN(E1/G(1))
3730 REM
3735 LET H7=H6*COS(T6)
3740 LET V5=3.0*X1/(2.0*E1)
3745 LET V6=-V5
3750 LET E2=G(1)/20.0
3755 LET E3=G(2)/20.0
3760 LET E4=-E2
3765 LET E5=-E3
3770 LET P6=Z(10)/A6
3775 LET P7=Z(10)/A6
3780 IF G6=1 THEN 3800
3785 PRINT TAB(31);"FAILED PILE"
3790 PRINT TAB(31);"_____ ____"
3795 GOTO 3807
3800 PRINT TAB(30);"REMAINING PILE"
3805 PRINT TAB(30);"_____ ____"
3807 PRINT
3810 PRINT USING 3590,M1
```

000033

```
3815 PRINT USING 3595,N4
3820 PRINT USING 3600,J3
3825 PRINT USING 3605,J4
3830 PRINT USING 3610,P4
3831 PRINT
3832 PRINT
3835 PRINT TAB(30);"PILE1(VERTICAL)"
3840 PRINT TAB(2);"DIST. FROM";TAB(34);"HOR.";TAB(48);"VER."
3845 PRINT TAB(1);"TOP OF PILE";TAB(20);"MOMENT";TAB(34);"SHEAR";TAB(48);
3848 PRINT "SHEAR";TAB(61);"STRESS"
3850 PRINT TAB(20);"(FT*K)";TAB(35);"(K)";TAB(49);"(K)";TAB(60);"(K/IN**2)"
3855 FOR K9=1 TO 21 STEP 1
3860 LET E4=E4+E2
3865 LET W(K9)=E4
3870 LET E5=E5+E3
3875 LET Z(7)=SQR(E5↑2-E4↑2)
3880 LET Z(5)=E1-Z(7)
3885 LET Z(6)=G(1)-E4
3890 LET Z(1)=Z(6)/G(1)*V3+E4/G(1)*V4
3892 LET W(K9+21)=Z(7)/E1*B2+Z(5)/E1*B1
3895 LET Z(3)=P6+Z(1)*Z(9)/A7
3900 LET W(K9+42)=P7+W(K9+21)*Z(9)/A7
3905 LET Z(3)=Z(3)/144.0
3910 LET W(K9+42)=W(K9+42)/144.0
3915 PRINT USING 3920,E4,Z(1),H6,V6,Z(3)
3920 :    ###.##        ###.####        ###.####        ###.####        ###.####
3925 NEXT K9
3930 PRINT
3935 PRINT
3940 PRINT TAB(30);"PILE 2(BATTERED)"
3945 PRINT TAB(3);"DIST. FORM";TAB(34);"HOR.";TAB(48);"VER."
3950 PRINT TAB(2);"TOP OF PILE";TAB(20);"MOMENT";TAB(34);"SHEAR";TAB(48);
3955 PRINT "SHEAR";TAB(61);"STRESS"
3960 PRINT TAB(19);"(FT**K)";TAB(35);"(K)";TAB(49);"(K)";TAB(60);"(K/IN**2)"
3965 FOR K9=1 TO 21 STEP 1
3970 PRINT USING 3980,W(K9),W(K9+21),H7,V5,W(K9+42)
3975 NEXT K9
3980 :    ###.##        ###.####        ###.####        ###.####        ###.####
3985 RETURN
4000 REM
4001 IF U6=0 THEN 4081
4002 FILE : 1,"P"
4004 SETW :1 TO 1
4006 WRITE :1,U6,X(6),X(7),X(8),X(9)
4008 FILE : 1,"AR"
4010 SETW :1 TO 1
4012 FOR I9=1 TO 25 STEP 1
4014 FOR J9=1 TO 18 STEP 1
4016 WRITE :1,L(I9,J9)
4018 NEXT J9
4020 NEXT I9
4022 FOR I9=1 TO 25 STEP 1
4024 WRITE :1,M(I9),T(I9),E(I9),U(I9),A(I9),F(I9),S(I9)
4026 NEXT I9
4028 FILE : 1,"AE"
4030 SETW :1 TO 1
4032 WRITE :1,F1,F2,K2,I,A5,F(I),I1,S4,S5,S6,T1,I3,T4,I2,T(I),D1,U1,A4
4034 FILE : 1,"AA"
4035 SETW :1 TO 7
4038 FOR I9=1 TO 30 STEP 1
4040 WRITE :1,O(I9),N(I9)
```

```
4042 NEXT I9
4044 FILE : 1,"P2"
4046 SETW :1 TO 1
4048 FOR I9=1 TO 30 STEP 1
4050 WRITE :1,N[I9]
4052 NEXT I9
4060 FILE : 1,"KLOOP"
4061 SETW :1 TO 1
4062 WRITE :1,I,K2
4070 REM
4080 CHAIN "*FRAME"
4081 FILE : 1,"AR"
4082 SETW :1 TO 1
4090 FOR I9=1 TO 30 STEP 1
4100 WRITE :1,O[I9],N[I9]
4110 NEXT I9
4120 WRITE :1,B[1]
4130 FOR I9=1 TO B[1] STEP 1
4140 WRITE :1,D[I9]
4150 NEXT I9
4160 WRITE :1,Y[2]
4170 FOR I9=1 TO Y[2] STEP 1
4180 WRITE :1,R[I9]
4190 NEXT I9
4200 FOR I9=1 TO 10 STEP 1
4210 FOR J9=1 TO 60 STEP 1
4220 WRITE :1,H[I9,J9]
4230 NEXT J9
4240 NEXT I9
4250 FOR I9=1 TO 25 STEP 1
4260 WRITE :1,M[I9],T[I9],E[I9],V[I9],A[I9],F[I9],S[I9]
4270 NEXT I9
4280 WRITE :1,I4,I1,N1,I7,N3,N2,I,S1,P3,Y1,K,Z[10],A6,Z[9],A7
4281 IF I4=1 THEN 4290
4282 WRITE :1,I5
4290 FOR I9=1 TO 25 STEP 1
4300 FOR J9=1 TO 18 STEP 1
4310 WRITE :1,L[I9,J9]
4320 NEXT J9
4330 NEXT I9
4340 FOR I9=1 TO K STEP 1
4350 WRITE :1,G[I9]
4360 NEXT I9
4370 CHAIN "*MAINL4"
9999 END

END OF LISTING



FILE    *MAINL1


0005 REM ********************************************************************
0010 REM SUBROUTINE MAINL1(MAINL-PILE TO DIAG)
0015 REM ********************************************************************
0016 DISP "        INPUT VERIFICATION"
0017 DCL SINGLE
0020 FILES COMM8;P;AB;AR
0025 SETW :1 TO 1
0030 SETW :2 TO 1
```

000035

```
0032 SETU :3 TO 1
0035 REM ----------------------------------------------------------------
0040 REM READ FROM FILES
0045 REM ----------------------------------------------------------------
0050 READ :1,J3,A3,B1,C1,M1,J5,J4
0055 ON J5 GOTO 60,65
0060 READ :1,W3,F1,T1,P3
0065 READ :1,N6
0070 IF J3<>1 THEN 80
0075 READ :1,N3
0080 IF J3<>0 THEN 90
0085 READ :1,J2
0090 READ :1,H4
0095 IF J3=0 THEN 110
0100 READ :1,E4,R5,R7,E5,R6,R8
0105 GOTO 115
0110 READ :1,E4,R5,R7
0115 IF J4=0 THEN 140
0120 READ :1,M2
0125 FOR J=1 TO M2 STEP 1
0130 READ :1,J,A(J),B(J)
0135 NEXT J
0140 READ :1,U1
0145 IF U1=1 THEN 170
0150 READ :1,N5
0155 FOR J=1 TO N5 STEP 1
0160 READ :1,N(J)
0165 NEXT J
0170 READ :1,N3,N6
0171 REM INITIALIZATION OF NTHIN,NZS,ISLOPT
0172 LET Z1=Z2=Z3=0
0175 REM ----------------------------------------------------------------
0180 REM DIMENSION
0185 DIM A(50),B(50),N(30),L(25,18),M(25),T(25),D(25),V(25),E(25),F(25),S(25)
0190 REM ----------------------------------------------------------------
1000 REM ----------------------------------------------------------------
1005 REM MAINLINE MAINL1
1010 REM ----------------------------------------------------------------
1015 IF J3<>1 THEN 1065
1020 GOSUB 1475
1025 PRINT "                    REGULAR RUBBER FENDER DATA"
1030 PRINT "                    ------- ------ ------ ----"
1035 PRINT
1040 PRINT USING 1042,A3
1042 :                    A  COEFFICIENT =    ####.####
1045 PRINT USING 1047,B1
1047 :                    B  COEFFICIENT =    ####.####
1050 PRINT USING 1052,C1
1052 :                    C  COEFFICIENT =    ####.####
1055 IF M1<=1E-3 THEN 1065
1060 PRINT USING 1062,M1
1062 :              MAXIMUM DEFLECTION =    ###.####   IN.
1065 ON J5 GOTO 1070,1110
1070 GOSUB 1475
1075 PRINT "                GRAVITY-RETRACTABLE FENDER DATA"
1080 PRINT "                -------------------- ------ ----"
1085 PRINT
1087 PRINT USING 1090,W3
1090 :              WEIGHT OF COUNTER-WEIGHT=    ####.####   K
1092 PRINT USING 1035,F1
1095 :            SUPPORT-COUNTER-WEIGHT DISTANCE=    ####.####   IN
```

```
1097 PRINT USING 1100,T1
1100 :                              ANGLE OF TRACT=     ####.####   DEG
1102 PRINT USING 1105,P3
1105 :                         COEFFICIENT OF FRICTION=     ####.####
1110 GOSUB 1475
1115 PRINT "                      SYSTEM CONFIGURATION DATA"
1120 PRINT "                      ------ ------------- ----"
1125 PRINT
1130 PRINT USING 1132,N6
1132 :                   NUMBER OF PILE GROUPS =      ###
1135 IF J3<>1 THEN 1145
1140 PRINT USING 1142,N3
1142 :                   NUMBER OF FENDERS =      ###
1145 IF J3<>0 THEN 1155
1150 PRINT USING 1152,J2
1152 :                   NUMBER OF FENDERS =      ###
1155 PRINT USING 1157,H4
1157 :              SPACING BETWEEN PILES =      ###.##   IN
1160 GOSUB 1475
1165 PRINT "                         BEAM PROPERTIES"
1170 PRINT "                         ---- ----------"
1175 PRINT
1180 IF J3=0 THEN 1250
1185 PRINT USING 1190,E4
1190 :         MODULUS OF ELASTICITY OF SUPPPORT BEAM = ######.## K/IN**2
1195 PRINT USING 1200,R5
1200 :           MOMENT OF INERTIA OF SUPPORT BEAM = ######.## IN**4
1205 PRINT USING 1210,R7
1210 :                   AREA OF SUPPORT BEAM = ######.## IN**2
1215 PRINT USING 1220,E5
1220 :          MODULUS OF ELASTICITY OF FENDER BEAM = ######.## K/IN**2
1225 PRINT USING 1230,R6
1230 :           MOMENT OF INERTIA OF FENDER BEAM = ######.## IN**4
1235 PRINT USING 1240,R8
1240 :                   AREA OF FENDER BEAM = ######.## IN**2
1245 GOTO 1265
1250 PRINT USING 1190,E4
1255 PRINT USING 1200,R5
1260 PRINT USING 1210,R7
1265 GOTO 1270
1270 IF J4=0 THEN 1330
1275 GOSUB 1475
1280 PRINT TAB(26);"COORDINATES OF JOINTS"
1285 PRINT TAB(26);"----------- -- ------"
1290 PRINT
1295 PRINT TAB(6);"JOINT";TAB(36);"X";TAB(64);"Y"
1300 PRINT TAB(6);"NUMBER";TAB(31);"COORDINATE";TAB(59);"COORDINATE"
1305 PRINT TAB(34);"(IN)";TAB(62);"(IN)"
1310 PRINT
1315 FOR J=1 TO M2 STEP 1
1320 PRINT USING 1325,J,A(J),B(J)
1325 :       ###                #####.####                #####.####
1327 NEXT J
1330 GOTO 1335
1335 IF U1=1 THEN 1385
1340 GOSUB 1475
1345 PRINT "          RIGID SUPPORT"
1350 PRINT "          ----- -------"
1355 PRINT
1360 PRINT "          SPRING NO."
1365 FOR J=1 TO N5 STEP 1
```

```
1370 PRINT USING 1375,N(J)
1375 :                ###
1380 NEXT J
1385 GOTO 1390
1390 IF J3<>1 THEN 1400
1395 LET M3=N3
1400 IF J3<>0 THEN 1410
1405 LET M3=N6
1410 IF J3<>1 THEN 1420
1415 LET M4=(N3-N6)/(N6-1)
1420 IF J3<>0 THEN 1427
1425 LET M4=0
1427 LET M5=J3
1429 GOTO 1510
1430 REM --------------------------------------------------------------
1435 REM CALL SUBROUTINE DIAG
1440 REM GOSUB
1445 REM --------------------------------------------------------------
1450 REM
1455 REM
1460 REM --------------------------------------------------------------
1465 REM PRINT SUBROUTINE
1470 REM --------------------------------------------------------------
1475 FOR I9=1 TO 4 STEP 1
1480 PRINT
1485 NEXT I9
1490 RETURN
1495 REM --------------------------------------------------------------
1500 REM WRITE INTO FILES
1505 REM --------------------------------------------------------------
1510 SETW :4 TO 1
1520 FOR I9=1 TO 25 STEP 1
1530 FOR J9=1 TO 18 STEP 1
1540 LET L(I9,J9)=0.0
1550 WRITE :4,L(I9,J9)
1560 NEXT J9
1570 NEXT I9
1580 FOR I9=1 TO 25 STEP 1
1590 LET M(I9)=T(I9)=D(I9)=V(I9)=E(I9)=F(I9)=S(I9)=0.0
1600 WRITE :4,M(I9),T(I9),D(I9),V(I9),E(I9),F(I9),S(I9)
1610 NEXT I9
1620 LET U6=0
1630 LET F(1)=1.0
1640 WRITE :2,U6,Z1,Z2,Z3,F(1)
1650 WRITE :3,M3,M5,M4
1660 DISP "REMOVE MAT OPT AND RUN *MAINL2"
1670 FOR I9=1 TO 3 STEP 1
1675 FOR K9=1 TO 100 STEP 1
1680 BEEP
1685 NEXT K9
1690 DELAY 6
1695 NEXT I9
9999 END

END OF LISTING
```

```
OLD *MAINL
LIST
FILE    *MAINL


0005 REM *************************************************************************
0010 REM SUBROUTINES MAINL AND INPUT
0015 REM *************************************************************************
0016 DISP "        INPUT VERIFICATION"
0017 DCL SINGLE
0018 DCL 400$
0020 FILES INPUT;COMM1;COMM2;COMM8;COMM9;COM6;COM8;CO9;ZA1;PO3;AA;BB;DRAW
0025 SETW :1 TO 1
0026 FOR I9=1 TO 6 STEP 1
0027 PRINT
0028 NEXT I9
0030 REM -----------------------------------------------------------------
0035 REM DIMENSIONING OF ARRAYS
0040 REM -----------------------------------------------------------------
0045 DIM A(25),H(30),S(40),T(25),D(25),B(25),C(25),N(30),F(20),L(25,18)
0050 DIM V(25),U(30),X(20),Y(20),M(20),E(20),P(10,3),G(64),R(64)
0185 REM -----------------------------------------------------------------
0190 REM MAINL BODY
0195 REM -----------------------------------------------------------------
0200 FOR I9=1 TO 25 STEP 1
0205 FOR J9=1 TO 18 STEP 1
0210 LET L(I9,J9)=0.0
0215 NEXT J9
0220 NEXT I9
0225 FOR I9=1 TO 25 STEP 1
0230 LET A(I9)=0.0
0235 NEXT I9
0240 LET N1=10
0245 LET J1=0.0
0250 LET L1=0.0
0255 LET J2=0.0
0260 FOR J9=1 TO 30 STEP 1
0265 LET H(J9)=0.0
0270 NEXT J9
0275 FOR J9=1 TO 40 STEP 1
0280 LET S(J9)=0.0
0285 NEXT J9
0290 LET D4=0.0
0295 LET A1=0.0
0300 LET D5=0.0
0305 LET A2=0.0
0310 LET T(1)=0.0
0315 LET D(1)=0.0
0320 LET B(1)=0.0
0324 LET C(1)=1.0
0325 LET I=1
0326 READ :1,0$
0327 PRINT TAB(10);"*************************************************************"
0328 PRINT TAB(10);"*";TAB(36);"JOB NAME:";TAB(68);"*"            000039
0329 PRINT TAB(10);"*";TAB(20);0$;TAB(68);"*"
0330 PRINT TAB(10);"*************************************************************"
0333 REM -----------------------------------------------------------------
0334 REM CALL SUBROUTINE INPUT
0335 GOSUB 660
```

```
0336 REM ------------------------------------------------------------
0340 IF U1=1 THEN 415
0345 IF J3<>0 THEN 355
0350 LET N2=0.0
0355 IF J3<>1 THEN 365
0360 LET N2=(N3-N6)/(N6-1)
0365 IF N5<>0 THEN 390
0370 LET N5=N6
0375 FOR J9=1 TO N5 STEP 1
0380 LET N(J9)=J9
0385 NEXT J9
0390 FOR J9=1 TO N5 STEP 1
0395 LET Q9=N(J9)+(N(J9)-1)*N2
0400 LET Q9=INT(Q9)
0405 LET H(Q9)=1
0410 NEXT J9
0415 GOTO 420
0420 LET A3=A4
0425 LET B1=B2
0430 LET C1=C2
0435 LET M1=D3
0440 LET P1=P2
0445 IF J4<>0 THEN 455
0450 LET P2=P2-45.0
0455 LET P2=P2*3.14159265/180
0460 LET W1=2.0*W
0465 LET S1=W1/(32.174*12.0)
0470 LET V1=308.0*V2/15.0
0475 LET A5=A6*3.14159265/180.0
0480 LET V(I)=V1*SIN(A5)
0485 GOSUB 1330
0490 GOSUB 1330
0495 PRINT "SHIP DATA"
0500 PRINT "____ ____"
0505 PRINT
0510 PRINT USING 515,W,W1
0515 :WEIGHT OF SHIP=                   ********.**   TONS        ********.**   K
0520 PRINT USING 525,V2,V1
0525 :VELOCITY OF SHIP=                  ********.**   KNOT        ********.**   IN/SEC
0530 PRINT USING 535,S1
0535 :MASS OF SHIP=                      ********.**   K*SEC**2/IN
0540 GOSUB 1330
0545 PRINT "LOAD DATA"
0550 PRINT "____ ____"
0555 PRINT
0560 PRINT USING 565,A6
0565 :ANGLE OF IMPACT=                   ********.**   DEG
0570 PRINT USING 575,P1
0575 :ANGLE BETWEEN LOAD AND X-AXIS=********.**   DEG
0580 PRINT "LOAD POINTS=";L2
0585 ON J5 GOTO 590,615
0590 LET W2=W3
0595 LET A5=T1*3.14159265/180.0
0600 LET A5=COS(A5)↑2
0605 LET A5=V(I)↑2-2.0*W2*P3*F1*A5/S1
0610 LET V(I)=SQR(A5)
0615 LET V3=V(I)
0620 LET V4=V(I)
0625 FOR I9=1 TO 30 STEP 1
0630 LET U(I9)=1
0635 NEXT I9
```

```
0640 GOTO 1360
0645 REM -------------------------------------------------------------
0650 REM SUBROUTINE INPUT
0655 REM -------------------------------------------------------------
0660 LET L3=0
0665 GOSUB 1330
0670 PRINT TAB(29);"VERIFICATION OF INPUT"
0675 PRINT TAB(29);"_____ __ _____"
0680 GOSUB 1310
0685 PRINT "OPTIONS INDICATED"
0690 PRINT
0695 READ :1,I1,I2,I3,I4,I5,I7,U1
0696 LET I6=2
0697 LET I8=1
0700 ON I1 GOTO 705,720,735
0705 PRINT "OPTION 1=1(ONE OR MORE VERTICAL PILES)"
0710 LET N4=1
0715 GOTO 745
0720 PRINT "OPTION 1=2(TWO BATTERED PILES)"
0725 LET N4=2
0730 GOTO 745
0735 PRINT "OPTION 1=3(GENERAL PILE CONFIGURATION)"
0740 LET N4=3
0745 ON I2 GOTO 750,770,790
0750 PRINT "OPTION 2=1(REGULAR RUBBER FENDERS)"
0755 LET J3=1
0760 LET J5=2
0765 GOTO 805
0770 PRINT "OPTION 2=2(GRAVITY-RETRACTABLE FENDERS)"
0775 LET J3=0
0780 LET J5=1
0785 GOTO 805
0790 PRINT "OPTION 2=3(NO FENDERS)"
0795 LET J3=0
0800 LET J5=2
0805 ON I3 GOTO 810,825
0810 PRINT "OPTION 3=1(JOINT COORDINATES GENERATED INTERNALLY)"
0815 LET J4=0
0820 GOTO 835
0825 PRINT "OPTION 3=2(JOINT COORDINATES INPUT)"
0830 LET J4=1
0835 ON I4 GOTO 840,850
0840 PRINT "OPTION 4=1(DEFLECTIONS ONLY OUTPUT)"
0845 GOTO 855
0850 PRINT "OPTION 4=2(DEFLECTIONS AND SPRING CONSTANTS OUTPUT)"
0855 ON I5 GOTO 860,875
0860 LET J6=1
0865 PRINT "OPTION 5=1(PILE GROUP ANALYSIS OUTPUT SUPPRESSED)"
0870 GOTO 905
0875 LET J6=2
0880 PRINT "OPTION 5=2(PILE GROUP ANALYSIS OUTPUT NOT SUPPRESSED)"
0905 ON I7 GOTO 910,920
0910 PRINT "OPTION 6=1(JOINT DISPLACEMENT TABLE NOT OUTPUT)"
0915 GOTO 945
0920 PRINT "OPTION 6=2(JOINT DISPLACEMENT TABLE OUTPUT)"
0945 ON U1 GOTO 950,960
0950 PRINT "OPTION 7=1(NO RIGID SUPPORTS)"
0955 GOTO 965
0960 PRINT "OPTION 7=2(ONE OR MORE RIGID SUPPORTS)"
0965 GOTO 970
0970 READ :1,W,V2
```

```
0975 READ  : 1,L2,A6,P2
0980 READ  : 1,G1,G3,E1
0985 ON N4 GOTO 990,1010,1050
0990 READ  : 1,K,S6
0995 READ  : 1,Z1,Z8,Z6,Z7,Z3,Z4
1000 READ  : 1,Z2,Z5,Z9,Y1,Y2
1005 GOTO 1125
1010 READ  : 1,H2
1020 READ  : 1,A7,D1,D2,A8,B3,A9,B4,B5,B6,C3
1030 FOR I9=1 TO 2 STEP 1
1035 READ  : 1,J,F(J)
1040 NEXT I9
1045 GOTO 1125
1050 READ  : 1,K,N7,N8,K5,K3,N9
1060 READ  : 1,A7,D1,D2,A8,B3,A9,B4,B5,B6,C3
1085 FOR I9=1 TO K STEP 1
1090 READ  : 1,J,X(J),Y(J),Z,M(J),E(J),F(J)
1095 NEXT I9
1100 READ  : 1,Q(1),Q(2),Q(3),Q(4),Q(5),Q(6)
1105 IF N9=0 THEN 1125
1110 FOR I9=1 TO N9 STEP 1
1115 READ  : 1,J,P(J,1),P(J,2),P(J,3)
1120 NEXT I9
1125 IF J3<>1 THEN 1135
1130 READ  : 1,A4,B2,C2,D3
1135 IF J5<>1 THEN 1145
1140 READ  : 1,W3,F1,T1,P3
1145 IF J3=1 THEN 1165
1150 LET A4=0.0
1155 LET B2=0.0
1160 LET C2=0.0
1162 LET D3=0.0
1165 READ  : 1,N6,N3,H3
1170 READ  : 1,E2,R1,R2
1175 IF J3<>1 THEN 1185
1180 READ  : 1,E3,R3,R4
1185 IF J4=0 THEN 1225
1190 IF J3<>0 THEN 1200
1195 LET L3=N6*2+2
1200 IF J3=0 THEN 1210
1205 LET L3=3*N3+4-(N3-N6)
1210 FOR I9=1 TO L3 STEP 1
1212 LET L3=INT(L3)
1215 READ  : 1,J,G(J),R(J)
1220 NEXT I9
1225 IF U1=1 THEN 1290
1230 READ  : 1,N5
1235 IF N5=0 THEN 1290
1240 LET L4=(N5+13)/14
1245 LET L4=INT(L4)
1250 FOR I9=1 TO L4 STEP 1
1255 LET J=(I-1)*14+1
1260 LET L5=J+13
1265 LET L5=INT(L5)
1270 FOR J9=J TO L5 STEP 1
1275 READ  : 1,N(J9)
1277 NEXT J9
1280 NEXT I9
1285 GOTO 1290
1290 RETURN
1295 REM ------------------------------------------------------------
```

```
1300 REM PRINT SUBROUTINES
1305 REM ------------------------------------------------------------
1310 FOR I9=1 TO 2 STEP 1
1315 PRINT
1320 NEXT I9
1325 RETURN
1330 FOR I9=1 TO 4 STEP 1
1335 PRINT
1340 NEXT I9
1345 RETURN
1350 REM ------------------------------------------------------------
1355 REM WRITE INTO FILES
1360 REM ------------------------------------------------------------
1395 IF N4=2 THEN 1399
1397 LET K8=K
1399 LET U2=0
1400 SETW :2 TO 1
1402 WRITE :2,G1,G3,E1,N4,N3,U2,J6
1405 ON N4 GOTO 1407,1411,1421
1407 WRITE :2,K,S6,Z1,Z2,Z3,Z4,Z5,Z6,Z7,Z8,Z9,Y1,Y2,K8
1409 GOTO 1500
1411 WRITE :2,H2,A7,D1,D2,A8,B3,A9,B4,B5,B6,C3
1413 FOR I9=1 TO 2 STEP 1
1415 WRITE :2,F(I9)
1417 NEXT I9
1419 GOTO 1500
1421 FOR I9=2 TO 6 STEP 1
1423 LET Q8=0.0
1425 NEXT I9
1427 WRITE :2,K,N9,N7,N8,K5,K3,K8
1429 FOR I9=1 TO K STEP 1
1431 WRITE :2,M(I9),E(I9),X(I9),Y(I9),Z,F(I9),A7
1433 NEXT I9
1434 WRITE :2,A9,A8,B3,B4,D1,D2,B5,B6,C3
1435 WRITE :2,Q(1),Q(2),Q(3),Q(4),Q(5),Q(6)
1437 IF N9=0 THEN 1500
1439 FOR I9=1 TO N9 STEP 1
1441 WRITE :2,P(I9,1),P(I9,2),P(I9,3)
1443 NEXT I9
1500 SETW :4 TO 1
1505 WRITE :4,J3,A3,B1,C1,M1,J5,J4
1510 ON J5 GOTO 1515,1520
1515 WRITE :4,W3,F1,T1,P3
1520 WRITE :4,N6
1525 IF J3<>1 THEN 1535
1530 WRITE :4,M3
1535 IF J3<>0 THEN 1545
1540 WRITE :4,J2
1545 WRITE :4,H3
1550 IF J3=0 THEN 1565
1555 WRITE :4,E2,R1,R2,E3,K3,R4
1560 GOTO 1570
1565 WRITE :4,E2,R1,R2
1570 IF J4=0 THEN 1595
1575 WRITE :4,L3
1580 FOR J=1 TO L3 STEP 1
1585 WRITE :4,J,G(J),R(J)
1590 NEXT J
1595 WRITE :4,U1
1600 IF U1=1 THEN 1625
1605 WRITE :4,N5
```

```
1610 FOR J=1 TO M5 STEP 1
1615 WRITE :4,N(J)
1620 NEXT J
1625 WRITE :4,N3,N6
1700 SETW :5 TO 1
1705 WRITE :5,I,C(I),D5,T(I),A6,P2,I,L2,N6,N3,L1,J3,J4,E1,H3,E2
1710 WRITE :5,R1,R2,N6,H3,E2
1712 IF J3=0 THEN 1715
1713 WRITE :5,R4,R3,E3
1715 FOR I9=1 TO 20 STEP 1
1720 WRITE :5,U(I9)
1725 NEXT I9
1730 FOR I9=1 TO 30 STEP 1
1735 WRITE :5,S(I9)
1740 NEXT I9
1790 SETW :6 TO 1
1795 WRITE :6,L3,A3,B1,C1
1800 FOR I9=1 TO L3 STEP 1
1805 WRITE :6,G(I9),R(I9)
1810 NEXT I9
1825 SETW :7 TO 1
1830 WRITE :7,A3,B1,C1,M1
1840 SETW :8 TO 1
1845 WRITE :8,I,C(I),T(I),P2,A6,S1,U(I),M1,V3,D4,A1,A2
1850 SETW :9 TO 1
1855 FOR I9=1 TO 30 STEP 1
1860 WRITE :9,H(I9)
1862 NEXT I9
1865 SETW :10 TO 1
1870 WRITE :10,I8
1889 SETW :11 TO 1
1890 WRITE :11,I7,J3,I4,M1,N4,J1
1891 FOR I9=1 TO 30 STEP 1
1892 WRITE :11,H(I9),U(I9)
1893 NEXT I9
1894 SETW :12 TO 1
1895 WRITE :12,I6
1900 REM ------------------------------------------------------------
1901 REM INPUT FOR DIAG
1902 REM ------------------------------------------------  ------------------
1903 IF J3<>1 THEN 1920
1910 LET Q7=N3
1920 IF J3<>0 THEN 1940
1930 LET Q7=N6
1940 IF J3<>1 THEN 1960
1950 LET Q8=INT((N3-N6)/(N6-1))
1960 IF J3<>0 THEN 1980
1970 LET Q8=0
1980 LET Q9=J3
1990 WRITE :13,Q7,Q8,Q9
2000 REM ------------------------------------------------------------
2010 CHAIN "*DIAG"
2020 REM ------------------------------------------------------------
9999 END

END OF LISTING
```

000044

```
OLD *MAINL1
LIST
FILE    *MAINL1


0005 REM *********************************************************************
0010 REM SUBROUTINE MAINL1(MAINL-PILE TO DIAG)
0015 REM *********************************************************************
0016 DISP "          INPUT VERIFICATION"
0017 DCL SINGLE
0020 FILES COMM8;P;AB;AR
0025 SETW :1 TO 1
0030 SETW :2 TO 1
0032 SETW :3 TO 1
0035 REM --------------------------------------------------------------
0040 REM READ FROM FILES
0045 REM --------------------------------------------------------------
0050 READ :1,J3,A3,B1,C1,M1,J5,J4
0055 ON J5 GOTO 60,65
0060 READ :1,W3,F1,T1,P3
0065 READ :1,N6
0070 IF J3<>1 THEN 80
0075 READ :1,N3
0080 IF J3<>0 THEN 90
0085 READ :1,J2
0090 READ :1,H4
0095 IF J3=0 THEN 110
0100 READ :1,E4,R5,R7,E5,R6,R8
0105 GOTO 115
0110 READ :1,E4,R5,R7
0115 IF J4=0 THEN 140
0120 READ :1,M2
0125 FOR J=1 TO M2 STEP 1
0130 READ :1,J,A(J),B(J)
0135 NEXT J
0140 READ :1,U1
0145 IF U1=1 THEN 170
0150 READ :1,N5
0155 FOR J=1 TO N5 STEP 1
0160 READ :1,N(J)
0165 NEXT J
0170 READ :1,N3,N6
0171 REM INITIALIZATION OF NTHIN,NZS,ISLDPT
0172 LET Z1=Z2=Z3=0
0175 REM --------------------------------------------------------------
0180 REM DIMENSION
0185 DIM A(50),B(50),N(30),L(25,18),M(25),T(25),D(25),V(25),E(25),F(25),S(25)
0190 REM --------------------------------------------------------------
1000 REM --------------------------------------------------------------
1005 REM MAINLINE MAINL1
1010 REM --------------------------------------------------------------
1015 IF J3<>1 THEN 1065
1020 GOSUB 1475
1025 PRINT "          REGULAR RUBBER FENDER DATA"
1030 PRINT "          ------- ------ ------ ----"          000045
1035 PRINT
1040 PRINT USING 1042,A3
1042 :              A  COEFFICIENT =    ####.####
1045 PRINT USING 1047,B1
```

```
1047 :                         B  COEFFICIENT =     ####.####
1050 PRINT USING 1052,C1
1052 :                         C  COEFFICIENT =     ####.####
1055 IF M1<=1E-3 THEN 1065
1060 PRINT USING 1062,M1
1062 :                    MAXIMUM DEFLECTION =     ###.####   IN.
1065 ON J5 GOTO 1070,1110
1070 GOSUB 1475
1075 PRINT "                   GRAVITY-RETRACTABLE FENDER DATA"
1080 PRINT "                   _____ _____ ____"
1085 PRINT
1087 PRINT USING 1090,W3
1090 :                WEIGHT OF COUNTER-WEIGHT=     ####.####    K
1092 PRINT USING 1095,F1
1095 :             SUPPORT-COUNTER-WEIGHT DISTANCE=     ####.####    IN
1097 PRINT USING 1100,T1
1100 :                        ANGLE OF TRACT=     ####.####    DEG
1102 PRINT USING 1105,P3
1105 :                COEFFICIENT OF FRICTION=     ####.####
1110 GOSUB 1475
1115 PRINT "                   SYSTEM CONFIGURATION DATA"
1120 PRINT "                   _____ _____ ____"
1125 PRINT
1130 PRINT USING 1132,N6
1132 :                    NUMBER OF PILE GROUPS =     ###
1135 IF J3<>1 THEN 1145
1140 PRINT USING 1142,N3
1142 :                    NUMBER OF FENDERS =     ###
1145 IF J3<>0 THEN 1155
1150 PRINT USING 1152,J2
1152 :                    NUMBER OF FENDERS =     ###
1155 PRINT USING 1157,H4
1157 :                SPACING BETWEEN PILES =     ###.##   IN
1160 GOSUB 1475
1165 PRINT "                        BEAM PROPERTIES"
1170 PRINT "                        ____ _____"
1175 PRINT
1180 IF J3=0 THEN 1250
1185 PRINT USING 1190,E4
1190 :          MODULUS OF ELASTICITY OF SUPPPORT BEAM = ######.## K/IN**2
1195 PRINT USING 1200,R5
1200 :             MOMENT OF INERTIA OF SUPPORT BEAM = ######.## IN**4
1205 PRINT USING 1210,R7
1210 :                    AREA OF SUPPORT BEAM = ######.## IN**2
1215 PRINT USING 1220,E5
1220 :          MODULUS OF ELASTICITY OF FENDER BEAM = ######.## K/IN**2
1225 PRINT USING 1230,R6
1230 :             MOMENT OF INERTIA OF FENDER BEAM = ######.## IN**4
1235 PRINT USING 1240,R8
1240 :                    AREA OF FENDER BEAM = ######.## IN**2
1245 GOTO 1265
1250 PRINT USING 1190,E4
1255 PRINT USING 1200,R5
1260 PRINT USING 1210,R7
1265 GOTO 1270
1270 IF J4=0 THEN 1330
1275 GOSUB 1475
1280 PRINT TAB(26);"COORDINATES OF JOINTS"
1285 PRINT TAB(26);"_____ __ _____"
1290 PRINT
1295 PRINT TAB(6);"JOINT";TAB(36);"X";TAB(64);"Y"
```

```
1300 PRINT TAB(6);"NUMBER";TAB(31);"COORDINATE";TAB(59);"COORDINATE"
1305 PRINT TAB(34);"(IN)";TAB(62);"(IN)"
1310 PRINT
1315 FOR J=1 TO M2 STEP 1
1320 PRINT USING 1325,J,A(J),B(J)
1325 :     ###                    #####.####                    #####.####
1327 NEXT J
1330 GOTO 1335
1335 IF U1=1 THEN 1385
1340 GOSUB 1475
1345 PRINT "            RIGID SUPPORT"
1350 PRINT "            _____ _____"
1355 PRINT
1360 PRINT "            SPRING NO."
1365 FOR J=1 TO N5 STEP 1
1370 PRINT USING 1375,N(J)
1375 :              ###
1380 NEXT J
1385 GOTO 1390
1390 IF J3<>1 THEN 1400
1395 LET M3=N3
1400 IF J3<>0 THEN 1410
1405 LET M3=N6
1410 IF J3<>1 THEN 1420
1415 LET M4=(N3-N6)/(N6-1)
1420 IF J3<>0 THEN 1427
1425 LET M4=0
1427 LET M5=J3
1429 GOTO 1510
1430 REM ------------------------------------------------
1435 REM CALL SUBROUTINE DIAG
1440 REM GOSUB
1445 REM ------------------------------------------------
1450 REM
1455 REM
1460 REM ------------------------------------------------
1465 REM PRINT SUBROUTINE
1470 REM ------------------------------------------------
1475 FOR I9=1 TO 4 STEP 1
1480 PRINT
1485 NEXT I9
1490 RETURN
1495 REM ------------------------------------------------
1500 REM WRITE INTO FILES
1505 REM ------------------------------------------------
1510 SETW :4 TO 1
1520 FOR I9=1 TO 25 STEP 1
1530 FOR J9=1 TO 18 STEP 1
1540 LET L(I9,J9)=0.0
1550 WRITE :4,L(I9,J9)
1560 NEXT J9
1570 NEXT I9
1580 FOR I9=1 TO 25 STEP 1
1590 LET M(I9)=T(I9)=D(I9)=V(I9)=E(I9)=F(I9)=S(I9)=0.0
1600 WRITE :4,M(I9),T(I9),D(I9),V(I9),E(I9),F(I9),S(I9)
1610 NEXT I9
1620 LET U6=0
1630 LET F(1)=1.0
1640 WRITE :2,U6,Z1,Z2,Z3,F(1)
1650 WRITE :3,M3,M5,M4
1660 DISP "REMOVE MAT OPT AND RUN *MAINL2"
```

```
1670 FOR I9=1 TO 3 STEP 1
1675 FOR K9=1 TO 100 STEP 1
1680 BEEP
1685 NEXT K9
1690 DELAY 6
1695 NEXT I9
9999 END

END OF LISTING



FILE    *MATRIX


0005 REM **************************************************************
0010 REM SUBROUTINE MATRIX(INCLUDES MEMST,CALC2,KVAL)
0011 REM **************************************************************
0012 DCL SN(),SQ(),SX(),SL(),SJ(),SK(),SR(),SP(),SG(),SA1,SM,SB3,SB2,SC3,S`',SB
0013 DCL SF1,SF2,SF3,SH5,SI1,SI2,SI3,SI4,SI5,SI8,SI6,SI7,SH1,SH2,SH3,SH4,SG1,SJ1
0014 DCL SJ2,SJ3,SG2,SK5,SK1,SK2,SK3,SK7,SK4,SK8,SL1,SL2,SM9,SM1,SM8,SN4,SN8,SN2
0015 DCL SN1,SN5,SN6,SP5,SQ1,SQ2,SQ3,SQ4,SR1,SR2,SR3,SS9,SS5,ST1,SU1,SZ1
0016 DCL SC(),SI(),SL(),SH(),SF()
0020 FILES COM7
0025 SETW :1 TO 1
0040 REM -------------------------------------------------------------
0045 REM READ FROM FILES
0050 REM -------------------------------------------------------------
0054 REM P3=NIXON, M9=M, P4=NJNJ
0055 READ :1,P3,M9,P4
0060 FOR I9=1 TO M9 STEP 1
0064 REM J(I9)=JJ(I), K(I9)=JK(I), C(I9)=AX(I), I(I9)=IZ(I), H(I9)=L(I)
0065 READ :1,J(I9),K(I9),C(I9),I(I9),H(I9)
0070 NEXT I9
0075 FOR I9=1 TO M9 STEP 1
0079 REM E(I9)=ES(I), V(I9)=XC(I), W(I9)=YC(I)
0080 READ :1,E(I9),V(I9),W(I9)
0085 NEXT I9
0090 FOR I9=1 TO P4 STEP 1
0094 REM P(I9)=RL(I), X(I9)=CRL(I), D(I9)=D(I)
0095 READ :1,P(I9),X(I9),D(I9)
0100 NEXT I9
0105 READ :1,N4,I8,N8,K4,N1
0107 FILE : 1,"COM8"
0108 SETW :1 TO 1
0110 READ :1,A1,B2,C4,M1
0115 READ :1,K7,B,H5,M8,L1
0120 FILE : 1,"CO1"
0125 SETW :1 TO 1
0135 READ :1,P2,F1
0136 FILE : 1,"CO3"
0137 SETW :1 TO 1
0138 FOR I9=1 TO 40 STEP 1
0139 READ :1,A(I9)
0141 NEXT I9
0142 READ :1,E1
0143 FOR I9=1 TO M9 STEP 1
0144 LET J(I9)=INT(J(I9))
0145 LET K(I9)=INT(K(I9))
0146 NEXT I9
0147 FOR I9=1 TO P4 STEP 1
```
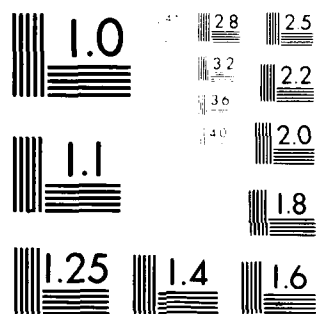
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS

```
0148 LET P(I9)=INT(P(I9))
0149 LET X(I9)=INT(X(I9))
0150 NEXT I9
0151 REM FOR I9=1 TO M9 STEP 1
0152 REM LET H(I9)=H(I9)+.001
0153 REM LET H(I9)=INT(H(I9))
0154 REM NEXT I9
0155 REM DEMENSIONING OF ARRAYS
0160 DIM J(50),K(50),C(50),I(50),E(50),H(50),U(50),U(50)
0165 DIM P(120),X(120),D(120),R(50),Y(96,15),A(40),F(30)
0170 REM -----------------------------------------------------------------
0175 REM
0180 REM
0182 FILE : 1,"POINT2"
0183 SETW :1 TO 1
0190 READ :1,U3
0195 IF U3=0 THEN 400
0197 FILE : 1,"PO2"
0200 SETW :1 TO 1
0205 READ :1,K4,K5,H5
0210 FOR I9=1 TO P4 STEP 1
0215 READ :1,D(I9)
0220 NEXT I9
0225 GOTO 435
0385 REM -----------------------------------------------------------------
0390 REM SUBROUTINE MAIN(FROM CALL INPT TO CALL MATRIX
0395 REM -----------------------------------------------------------------
0400 FOR I9=1 TO M9 STEP 1
0405 LET R(I9)=0.0
0410 NEXT I9
0415 LET Q1=0
0420 LET K5=H5
0425 LET H5=0
0430 GOTO 435
0435 FOR I9=1 TO M8 STEP 1
0440 FOR J9=1 TO K5 STEP 1
0445 LET Y(I9,J9)=0.0
0450 NEXT J9
0455 NEXT I9
0485 REM -----------------------------------------------------------------
0490 REM MAINLINE MATRIX
0495 REM -----------------------------------------------------------------
0500 LET I1=N4+1
0505 LET I1=INT(I1)
0510 FOR I9=1 TO I1 STEP 1
0515 LET J1=3*J(I9)-2
0520 LET J2=3*J(I9)-1
0525 LET J3=3*J(I9)
0530 LET K1=3*K(I9)-2
0535 LET K2=3*K(I9)-1
0540 LET K3=3*K(I9)
0545 LET S1=E(I9)*C(I9)/H(I9)
0550 LET S2=4.0*E(I9)*I(I9)/H(I9)
0555 LET S3=1.5*S2/H(I9)
0560 LET S4=2.0*S3/H(I9)
0565 REM -----------------------------------------------------------------
0570 REM CALL SUBROUTINES
0575 GOSUB 1405
0580 GOSUB 1615
0585 REM -----------------------------------------------------------------
0590 NEXT I9
```

```
0597 LET I2=I1+1
0600 LET I3=I2+N4
0605 LET I2=INT(I2)
0610 LET I3=INT(I3)
0615 FOR I9=I2 TO I3 STEP 1
0620 LET J1=3*J(I9)-2
0625 LET J2=3*J(I9)-1
0630 LET J3=3*J(I9)
0633 LET K1=3*K(I9)-2
0640 LET K2=3*K(I9)-1
0645 LET K3=3*K(I9)
0650 LET S1=E(I9)*C(I9)/H(I9)
0655 LET S2=4.0*E(I9)*I(I9)/H(I9)
0660 LET S3=1.5*S2/H(I9)
0665 LET S4=2.0*S3/H(I9)
0670 REM --------------------------------------------------
0675 REM CALL SUBROUTINES
0680 GOSUB 1405
0685 GOSUB 1615
0690 REM --------------------------------------------------
0695 NEXT I9
0696 FILE : 1,"COM9"
0697 SETW :1 TO 1
0698 FOR I9=1 TO 20 STEP 1
0699 READ :1,I(I9)
0700 NEXT I9
0701 FOR I9=1 TO 30 STEP 1
0702 READ :1,F(I9)
0703 NEXT I9
0704 FOR I9=1 TO N8 STEP 1
0705 READ :1,E(I9)
0706 NEXT I9
0707 IF L1=1 THEN 712
0708 FILE : 1,"P2"
0709 FOR I9=1 TO 30 STEP 1
0710 READ :1,F(I9)
0711 NEXT I9
0712 IF U3=0 THEN 721
0713 FILE : 1,"PO2"
0714 READ :1,U1,U1,U1
0715 FOR I9=1 TO P4 STEP 1
0716 READ :1,U1
0717 NEXT I9
0718 FOR I9=1 TO N8 STEP 1
0719 READ :1,I(I9)
0720 NEXT I9
0721 LET I4=I3+1
0722 LET I5=I3+N4
0723 IF I8=0 THEN 920
0724 LET I6=0
0725 LET I4=INT(I4)
0726 LET I5=INT(I5)
0727 FILE : 1,"COM4"
0730 FOR I9=I4 TO I5 STEP 1
0735 LET I6=I6+1
0740 LET J1=3*J(I9)-2
0745 LET J2=3*J(I9)-1
0750 LET J3=3*J(I9)
0755 LET K1=3*K(I9)-2
0760 LET K2=3*K(I9)-1
0765 LET K3=3*K(I9)
```

```
0770 IF I8=0 THEN 810
0775 LET D1=D(K2)-D(J2)
0780 LET D2=D(K1)-D(J1)
0785 LET D1=SQR(D1↑2+D2↑2)
0790 REM --------------------------------------------------
0795 REM CALL SUBROUTINE
0800 GOSUB 1980
0805 REM --------------------------------------------------
0810 LET I7=I6+N8
0815 IF I8<>0 THEN 822
0820 LET R1=R(I9+N4)
0822 SETW :1 TO I7
0825 WRITE :1,R1
0830 LET R(I9)=R1
0835 LET S1=R(I9)
0840 LET B1=0.0
0845 FOR J9=1 TO K7 STEP 1
0850 LET B1=B1+B
0855 NEXT J9
0860 LET S2=7000
0865 IF I8<>0 THEN 875
0870 LET S2=S9
0875 LET S3=1.5*S2/H(I9)
0880 LET S4=2.0*S3/H(I9)
0885 REM --------------------------------------------------
0890 REM CALL SUBROUTINES
0895 GOSUB 1405
0900 GOSUB 1615
0905 REM --------------------------------------------------
0910 NEXT I9
0915 IF I8=0 THEN 2110
0920 GOTO 925
0925 LET H1=I5+1
0930 LET H2=I5+N8
0935 LET H3=0
0940 LET H4=N4*3+2
0945 LET H1=INT(H1)
0949 LET H2=INT(H2)
0950 FILE : 1,"ZA1"
0951 SETW :1 TO 1
0952 FOR K9=1 TO 30 STEP 1
0953 READ :1,C(K9)
0954 NEXT K9
0955 FILE : 1,"COM4"
0956 FOR I9=H1 TO H2 STEP 1
0960 LET H3=H3+1
0965 LET J1=3*J(I9)-2
0970 LET J2=3*J(I9)-1
0975 LET J3=3*J(I9)
0980 LET K1=3*K(I9)-2
0985 LET K2=3*K(I9)-1
0990 LET K3=3*K(I9)
0995 IF K4=1 THEN 1101
1000 LET D1=D(K2)-D(J2)
1005 LET D1=ABS(D1)
1010 LET D2=D(K1)-D(J1)
1015 LET D1=SQR(D2↑2+D1↑2)
1016 REM PRINT USING 1017,D1
1017 : D1= ########.########
1020 LET R(I9)=E(H3)↑2*D1
1025 LET P1=R(I9)*I(I9-H4)
```

```
1030 IF INT(F(I9-H4))<>0 THEN 1045
1035 IF P1<=P2 THEN 1045
1040 LET R(I9)=P2/I(I9-H4)
1045 IF I8<>0 THEN 1055
1050 LET R(I9)=R(I9)/2
1055 IF I8<>1 THEN 1075
1056 REM PRINT I8,C(I9-H4),R(I9)
1060 IF INT(F(I9-H4))<>1 THEN 1075
1065 IF R(I9)>=1.0 THEN 1075
1070 LET R(I9)=1.0
1075 IF I8<>0 THEN 1091
1080 IF INT(F(I9-H4))<>1 THEN 1091
1085 IF R(I9)>=0.5 THEN 1091
1090 LET R(I9)=0.5
1091 GOTO 1180
1101 LET R(I9)=A(H3)
1105 LET P1=R(I9)*I(I9-H4)
1110 IF INT(F(I9-H4))<>0 THEN 1125
1115 IF P1<=P2 THEN 1125
1120 LET R(I9)=P2/I(I9-H4)
1125 IF I8<>0 THEN 1140
1130 IF L1=1 THEN 1140
1135 LET R(I9)=R(I9)/2.0
1140 IF I8<>1 THEN 1160
1145 IF INT(F(I9-H4))<>1 THEN 1160
1150 IF R(I9)>=1.0 THEN 1160
1155 LET R(I9)=1.0
1160 IF I8<>0 THEN 1180
1165 IF INT(F(I9-H4))<>1 THEN 1180
1170 IF R(I9)>=0.5 THEN 1180
1175 LET R(I9)=0.5
1180 GOTO 1185
1185 LET N2=N1
1190 LET N1=N1+1
1195 LET H1=INT(H1)
1200 LET H2=INT(H2)
1205 LET N1=INT(N1)
1210 FOR J9=H1 TO H2 STEP N1
1215 IF I9=J9 THEN 1230
1220 NEXT J9
1225 LET R(I9)=0.0001
1230 GOTO 1231
1231 LET N1=N2
1240 IF C(I9-H4)<>1 THEN 1250
1245 LET R(I9)=1E7
1250 IF I8<>0 THEN 1257
1255 LET R(I9)=R(I9)*2.0
1257 SETW :1 TO H3
1260 WRITE :1,R(I9)
1265 LET B1=0.0
1270 FOR J9=1 TO K7 STEP 1
1271 REM PRINT USING 1272,B
1272 : B=####.######
1275 LET B1=B1+B
1280 NEXT J9
1285 LET S1=R(I9)
1290 LET S2=E1*B1/F1*12
1291 REM PRINT USING 1292,S1,S2
1292 :   S1= ########.########   S2= ########.########
1295 IF S2<=14000.0 THEN 1305
1300 LET S2=14000.0
```

```
1305 IF S2>=7000.0 THEN 1315
1310 LET S2=7000.0
1315 LET S9=S2
1320 LET S3=1.5*S2/H(I9)
1325 LET S4=2.0*S3/H(I9)
1330 REM ---------------------------------------------------------------
1331 : BI=########.#### EE=########.#### FL=###.# PMAX=########.## K=### NZS=##
1335 REM CALL SUBROUTINES
1340 GOSUB 1405
1345 GOSUB 1615
1350 REM ---------------------------------------------------------------
1355 NEXT I9
1356 REM FOR I9=1 TO 61 STEP 1
1357 REM FOR J9=1 TO 10 STEP 1
1358 REM IF Y(I9,J9)=0.0 THEN 1360
1359 REM PRINT USING 1360,I9,J9,Y(I9,J9)
1360 REM :    Y(###,###)= #########.#########
1361 REM NEXT J9
1362 REM NEXT I9
1363 IF I8=0 THEN 1374
1364 GOTO 2110
1365 FILE : 1,"CO2"
1366 SETW :1 TO 90
1367 FOR I9=1 TO 30 STEP 1
1368 WRITE :1,C(I9)
1369 NEXT I9
1370 SETW :1 TO 1
1371 FOR I9=1 TO 82 STEP 1
1372 READ :1,C(I9)
1373 NEXT I9
1374 GOTO 724
1375 REM ===============================================================
1376 REM SUBROUTINES
1380 REM ===============================================================
1385 REM
1390 REM ---------------------------------------------------------------
1395 REM SUBROUTINE MEMST
1400 REM ---------------------------------------------------------------
1405 LET C1=V(I9)
1410 LET C2=W(I9)
1415 LET Z(1,1)=S1*C1↑2+S4*C2↑2
1420 LET Z(4,4)=S1*C1↑2+S4*C2↑2
1425 LET Z(1,4)=-Z(1,1)
1430 LET Z(4,1)=-Z(1,1)
1435 LET Z(1,2)=(S1-S4)*C1*C2
1440 LET Z(2,1)=(S1-S4)*C1*C2
1445 LET Z(4,5)=(S1-S4)*C1*C2
1450 LET Z(5,4)=(S1-S4)*C1*C2
1455 LET Z(1,5)=-Z(1,2)
1460 LET Z(5,1)=-Z(1,2)
1465 LET Z(2,4)=-Z(1,2)
1470 LET Z(4,2)=-Z(1,2)
1475 LET Z(1,3)=-S3*C2
1480 LET Z(3,1)=-S3*C2
1485 LET Z(1,6)=-S3*C2
1490 LET Z(6,1)=-S3*C2
1495 LET Z(3,4)=-Z(1,3)
1500 LET Z(4,3)=-Z(1,3)
1505 LET Z(4,6)=-Z(1,3)
1510 LET Z(6,4)=-Z(1,3)
1515 LET Z(2,2)=S1*C2↑2+S4*C1↑2
```

```
1520 LET Z(5,5)=S1*C2†2+S4*C1†2
1525 LET Z(2,5)=-Z(2,2)
1530 LET Z(5,2)=-Z(2,2)
1535 LET Z(2,3)=S3*C1
1540 LET Z(3,2)=S3*C1
1545 LET Z(2,6)=S3*C1
1550 LET Z(6,2)=S3*C1
1555 LET Z(3,5)=-Z(2,3)
1560 LET Z(5,3)=-Z(2,3)
1565 LET Z(5,6)=-Z(2,3)
1570 LET Z(6,5)=-Z(2,3)
1575 LET Z(3,3)=S2
1580 LET Z(6,6)=S2
1585 LET Z(3,6)=S2/2
1590 LET Z(6,3)=S2/2
1595 RETURN
1600 REM -------------------------------------------
1605 REM SUBROUTINE CALC2
1610 REM -------------------------------------------
1615 IF P(J1)<>0 THEN 1710
1620 LET R2=J1-X(J1)
1625 LET Y(R2,1)=Y(R2,1)+Z(1,1)
1630 IF P(J2)<>0 THEN 1640
1635 LET Y(R2,2)=Y(R2,2)+Z(1,2)
1640 IF P(J3)<>0 THEN 1655
1645 LET C3=J3-X(J3)-R2+1
1650 LET Y(R2,C3)=Y(R2,C3)+Z(1,3)
1655 IF P(K1)<>0 THEN 1670
1660 LET C3=K1-X(K1)-R2+1
1665 LET Y(R2,C3)=Z(1,4)
1670 IF P(K2)<>0 THEN 1685
1675 LET C3=K2-X(K2)-R2+1
1680 LET Y(R2,C3)=Z(1,5)
1685 IF P(K3)<>0 THEN 1700
1690 LET C3=K3-X(K3)-R2+1
1695 LET Y(R2,C3)=Z(1,6)
1700 IF C3-H5<=0 THEN 1710
1705 LET H5=C3
1710 IF P(J2)<>0 THEN 1790
1715 LET R2=J2-X(J2)
1720 LET Y(R2,1)=Y(R2,1)+Z(2,2)
1725 IF P(J3)<>0 THEN 1735
1730 LET Y(R2,2)=Y(R2,2)+Z(2,3)
1735 IF P(K1)<>0 THEN 1750
1740 LET C3=K1-X(K1)-R2+1
1745 LET Y(R2,C3)=Z(2,4)
1750 IF P(K2)<>0 THEN 1765
1755 LET C3=K2-X(K2)-R2+1
1760 LET Y(R2,C3)=Z(2,5)
1765 IF P(K3)<>0 THEN 1780
1770 LET C3=K3-X(K3)-R2+1
1775 LET Y(R2,C3)=Z(2,6)
1780 IF C3-H5<=0 THEN 1790
1785 LET H5=C3
1790 IF P(J3)<>0 THEN 1860
1795 LET R2=J3-X(J3)
1800 LET Y(R2,1)=Y(R2,1)+Z(3,3)
1805 IF P(K1)<>0 THEN 1820
1810 LET C3=K1-X(K1)-R2+1
1815 LET Y(R2,C3)=Z(3,4)
1820 IF P(K2)<>0 THEN 1835
```

```
1825 LET C3=K2-X(K2)-R2+1
1830 LET Y(R2,C3)=Z(3,5)
1835 IF P(K3)<>0 THEN 1850
1840 LET C3=K3-X(K3)-R2+1
1845 LET Y(R2,C3)=Z(3,6)
1850 IF C3-H5<=0 THEN 1860
1855 LET H5=C3
1860 IF P(K1)<>0 THEN 1900
1865 LET R2=K1-X(K1)
1870 LET Y(R2,1)=Y(R2,1)+Z(4,4)
1875 IF P(K2)<>0 THEN 1885
1880 LET Y(R2,2)=Y(R2,2)+Z(4,5)
1885 IF P(K3)<>0 THEN 1900
1890 LET C3=K3-X(K3)-R2+1
1895 LET Y(R2,C3)=Y(R2,C3)+Z(4,6)
1900 IF P(K2)<>0 THEN 1925
1905 LET R2=K2-X(K2)
1910 LET Y(R2,1)=Y(R2,1)+Z(5,5)
1915 IF P(K3)<>0 THEN 1925
1920 LET Y(R2,2)=Y(R2,2)+Z(5,6)
1925 IF P(K3)<>0 THEN 1940
1930 LET R2=K3-X(K3)
1935 LET Y(R2,1)=Y(R2,1)+Z(6,6)
1940 GOTO 1945
1945 IF H5<=K5 THEN 1960
1950 PRINT USING 1955,H5,K5
1955 :TRUE BANDWIDTH ##### IS GREATER THAN INTIAL VALUE #####
1960 RETURN
1965 REM ------------------------------------------------------------
1970 REM SUBROUTINE KVAL
1975 REM ------------------------------------------------------------
1980 LET D1=ABS(D1)
1985 IF M1>=1E-3 THEN 2085
1990 IF ABS(A1)<=1E-4 THEN 2050
1995 LET D3=B2/(2.0*A1)
2000 REM
2005 REM RLINE=THE LIMITING VALUE OF K TO BE USED, THIS
2010 REM IS WHERE MAX DEFLECTION IS REACHED
2015 REM
2020 LET D3=ABS(D3)
2025 LET R3=A1*D3↑2+B2*D3+C4
2030 LET R1=R3
2035 IF D1>=D3 THEN 2045
2040 LET R1=A1*D1↑2+B2*D1+C4
2045 GOTO 2101
2050 GOTO 2075
2055 REM
2060 REM IF CONTROL REACHES HERE THE K TERM IS A STRAIGHT
2065 REM LINE FUNCTION
2070 REM
2075 LET D3=C4/B2
2080 GOTO 2020
2085 LET D3=M1
2090 LET R1=A1*D3↑2+B2*D3+C4
2095 IF D1>=D3 THEN 2101
2100 LET R1=A1*D1↑2+B2*D1+C4
2101 RETURN
2110 REM ------------------------------------------------------------
2115 REM FILE OUTPUT
2120 REM ------------------------------------------------------------
2122 FILE : 1,"PO1"
```

```
2125 SETW :9 TO 1
2130 WRITE :1,M9,K5,K3,K4,N9,B1,........,P9,T9,C9,U9
2132 REM PRINT USING 2133,K5,H5
2133 : K5= #####    H5= #####
2135 FOR I9=1 TO M9 STEP 1
2140 FOR J9=1 TO K5 STEP 1
2145 WRITE :1,Y(I9,J9)
2150 NEXT J9
2155 NEXT I9
2160 FOR I9=1 TO P4 STEP 1
2165 WRITE :1,X(I9),P(I9)
2166 NEXT I9
2167 FOR I9=1 TO P4 STEP 1
2168 WRITE :1,D(I9),D(I9)
2169 NEXT I9
3000 REM -------------------------------------------------
3005 REM CHAIN STATEMENT
3010 CHAIN "*MAIN1"
3015 REM -------------------------------------------------
5000 END

END OF LISTING


OLD *INPUT1
ERROR  187
OLD *INPT1
LIST
FILE    *INPT1


0005 REM ************************************************************************
0010 REM SUBROUTINE INPT1
0015 REM ************************************************************************
0020 REM
0025 REM
0030 REM -------------------------------------------------
0035 REM FILE INPUT
0040 REM -------------------------------------------------
0042 DCL SO(),SP(),SQ(),SR(),ST(),SN(),SJ(),SK(),SC(),SI(),SE(),SU(),SV(),SM()
0043 DCL SM9
0045 FILES COM1
0050 SETW :1 TO 2
0060 READ :1,I1,L1,K1,I2,M1,N3,N4,P1,M9,A4,A5,A3,A2,R4,R5,R6,R7
0065 READ :1,E7,E5,E6,E8,H3,V1,F2,F3,Q1,Q3,M9,F3,M8,M3
0066 FILE : 1,"COM6"
0067 SETW :1 TO 1
0070 READ :1,L3,A6,B2,C3
0075 FOR I9=1 TO L3 STEP 1
0080 READ :1,A(I9),B(I9)
0085 NEXT I9
0086 FILE : 1,"P"
0087 SETW :1 TO 1
0088 READ :1,T5,M9,T6,T7,T8
0089 REM -------------------------------------------------------------- 000056--
0090 REM DIMENSIONING OF ARRAYS
0095 REM -------------------------------------------------
0100 DIM D(120),U(50),V(50),P(50),Q(50),R(50),S(50)
0105 DIM A(64),B(64),O(120),T(10),W(120),Z(62),N(50)
0110 DIM M(50,2),G(50),F(50),C(50),H(50),I(50),L(50)
```

```
0115 DIM J(50),K(50),E(50),X(64),Y(64),H(50)
0250 REM ??????????????????????????????????????????????????????????????????
0255 REM MYSTERY VARIABLE
0260 LET F4=0
0262 LET P3=0
0265 REM ??????????????????????????????????????????????????????????????????
0285 REM -------------------------------------------------------------------
0290 REM SUBROUTINE MAIN(FROM START TO CALL INPT)
0295 REM -------------------------------------------------------------------
0300 IF L1<>1 THEN 310
0302 FILE : 1,"ZZ1"
0303 SETW :1 TO 1
0305 WRITE :1,A6,B2,C3,P3
0310 IF L1=1 THEN 320
0312 FILE : 1,"ZZ1"
0313 SETW :1 TO 1
0315 READ :1,A6,B2,C3,P3
0320 LET K3=1
0325 IF L1<>1 THEN 348
0330 IF K1<>0 THEN 348
0335 FOR I9=1 TO M9 STEP 1
0340 LET D(I9)=0.0
0345 NEXT I9
0347 GOTO 354
0348 FILE : 1,"OY"
0349 SETW :1 TO 1
0350 READ :1,W9
0351 FOR I9=1 TO W9 STEP 1
0352 READ :1,D(I9)
0353 NEXT I9
0354 REM FILE : 1,"P7"
0355 REM SETW :1 TO 1
0356 REM READ :1,L6
0357 REM IF K1<>0 THEN 363
0358 REM IF L6<>L1 THEN 363
0359 REM READ :1,O7
0360 REM FOR I9=1 TO O7 STEP 1
0361 REM READ :1,D(I9)
0362 REM NEXT I9
0363 LET Q2=Q1
0365 IF F4<=F3 THEN 375
0370 LET Q2=Q3
0375 LET D3=SQR(D(Q2*3-1)↑2+D(Q2*3-2)↑2)
0485 REM -------------------------------------------------------------------
0490 REM MAINLINE INPT1
0495 REM -------------------------------------------------------------------
0500 IF I1=0 THEN 2015
0505 IF L1=1 THEN 515
0510 GOTO 1970
0515 IF K1=0 THEN 525
0520 GOTO 1970
0525 IF I2<>1 THEN 540
0530 IF N1<>0 THEN 540
0535 LET N2=N3
0540 IF I2<>0 THEN 550
0545 LET N2=2*N4+2
0550 IF I2<>1 THEN 565
0555 IF N1<=0 THEN 565
0560 LET N2=N3-(N4-(INT(N4/(N1+1))+1))
0565 IF I2<>1 THEN 580
0570 IF N1<>0 THEN 580
```

000057

```
0575 GOTO 585
0580 GOTO 640
0585 LET N3=INT(N3)
0590 FOR J9=1 TO N3 STEP 1
0595 LET X(J9)=A(J9)
0600 LET Y(J9)=B(J9)
0605 NEXT J9
0610 LET L2=4*N4+2
0615 LET L2=INT(L2)
0620 FOR J9=1 TO L2 STEP 1
0625 LET M(J9)=J9
0630 NEXT J9
0635 GOTO 1370
0640 IF I2=0 THEN 650
0645 GOTO 1165
0650 LET L2=N4+2
0655 LET K2=-1
0660 LET L3=-1
0665 LET L2=INT(L2)
0670 FOR J9=1 TO L2 STEP 1
0675 LET K2=K2+2
0680 LET L3=L3+3
0685 IF J9<>L2 THEN 700
0690 LET K2=K2-1
0695 LET L3=L3-1
0700 LET X(L3)=A(K2)
0705 LET Y(L3)=B(K2)
0710 NEXT J9
0715 LET K2=0
0720 LET L3=0
0725 LET N4=INT(N4)
0730 FOR J9=1 TO N4 STEP 1
0735 LET K2=K2+2
0740 LET L3=L3+3
0745 LET X(L3)=A(K2)
0750 LET Y(L3)=B(K2)
0755 NEXT J9
0760 LET K2=1
0765 LET L3=0
0770 LET M1=1
0775 FOR J9=1 TO N4 STEP 1
0780 LET K2=K2+2
0785 LET L3=L3+2
0790 LET M1=M1+3
0795 LET X(M1)=(A(K2)+A(L3))/2.0
0800 LET Y(M1)=(B(K2)+B(L3))/2.0
0805 NEXT J9
0810 LET O(1)=X(4)
0815 LET P(1)=Y(4)
0820 LET Q(1)=X(5)
0825 LET R(1)=Y(5)
0830 LET S(1)=X(2)
0835 LET T(1)=Y(2)
0840 LET I3=3*N4+1
0845 LET I3=INT(I3)
0850 LET O(2)=X(I3)
0855 LET P(2)=Y(I3)
0860 LET I3=3*N4+2
0865 LET I3=INT(I3)
0870 LET Q(2)=X(I3)
0875 LET R(2)=Y(I3)
```

```
0880 LET I3=3*N4+4
0885 LET I3=INT(I3)
0890 LET S(2)=X(I3)
0895 LET T(2)=Y(I3)
0900 FOR J9=1 TO 2 STEP 1
0905 LET S1=(R(J9)-T(J9))/(Q(J9)-S(J9))
0910 LET C1=P(J9)-S1*O(J9)
0915 LET C2=(Q(J9)-O(J9))↑2+(R(J9)-P(J9))↑2
0920 LET C2=C2-S(J9)↑2-T(J9)↑2
0925 LET C2=C2-C1↑2+2.0*C1*T(J9)
0930 LET C2=-C2
0935 LET B1=2.0*S1*C1-2.0*S1*T(J9)-2.0*S(J9)
0940 LET A1=S1↑2+1.0
0945 LET R1=B1↑2-4.0*A1*C2
0950 IF R1>0 THEN 960
0955 LET R1=0.0
0960 IF R1<=0.0 THEN 970
0965 LET R1=SQR(R1)
0970 LET X1=(-B1-R1)/(2.0*A1)
0975 LET Y1=S1*X1+C1
0980 LET X2=(-B1+R1)/(2.0*A1)
0985 LET Y2=S1*X2+C1
0990 LET D1=SQR((O(J9)-X1)↑2+(P(J9)-Y1)↑2)
0995 LET D2=(O(J9)-X2)↑2+(P(J9)-Y2)↑2
1000 IF D2<D1 THEN 1020
1005 LET W(J9)=X1
1010 LET Z(J9)=Y1
1015 GOTO 1030
1020 LET W(J9)=X2
1025 LET Z(J9)=Y2
1030 NEXT J9
1035 LET X(1)=W(1)
1040 LET Y(1)=Z(1)
1045 LET I3=3*N4+3
1050 LET I3=INT(I3)
1055 LET X(I3)=W(2)
1057 LET Y(I3)=Z(2)
1060 LET L2=N4+1
1065 LET L2=INT(L2)
1070 FOR J9=1 TO L2 STEP 1
1075 LET M(J9)=J9
1080 NEXT J9
1085 LET K2=3*N4+2
1090 LET L3=2*N4+2
1095 LET L2=N4+2
1100 LET L4=2*N4+1
1105 LET L2=INT(L2)
1110 LET L4=INT(L4)
1115 FOR J9=L2 TO L4 STEP 1
1120 LET M(J9)=0
1125 LET K2=K2+1
1130 LET L3=L3+1
1135 LET K2=INT(K2)
1140 LET L3=INT(L3)
1145 LET N(J9,1)=K2
1150 LET N(J9,2)=L3
1155 NEXT J9
1160 GOTO 1370
1165 LET K2=0
1170 LET N5=0
1175 LET N6=N1+1
```

```
1180 LET N3=INT(N3)
1185 FOR J9=1 TO N3 STEP 1
1190 LET J1=INT(J9/3)*3
1195 IF J9<>J1 THEN 1260
1200 LET N5=N5+1
1205 LET N4=INT(N4)
1210 LET N6=INT(N6)
1215 FOR I9=1 TO N4 STEP N6
1220 IF N5=I9 THEN 1260
1222 NEXT I9
1225 LET I4=N3-1
1230 IF J9>=I4 THEN 1260
1235 LET X3=A(K2+2)-A(K2+1)
1240 LET Y3=B(K2+2)-B(K2+1)
1245 LET X(J9)=A(K2+1)-X3
1250 LET Y(J9)=B(K2+1)-Y3
1255 GOTO 1275
1260 LET K2=K2+1
1265 LET X(J9)=A(K2)
1270 LET Y(J9)=B(K2)
1275 NEXT J9
1280 LET L2=3*N4+2
1285 LET L2=INT(L2)
1290 FOR J9=1 TO L2 STEP 1
1295 LET M(J9)=J9
1300 NEXT J9
1305 LET L2=INT(N4/(N1+1))+1
1310 LET K2=3*N4+2
1315 LET L3=K2-N1
1320 LET L2=INT(L2)
1325 LET K2=INT(K2)
1330 LET L3=INT(L3)
1335 FOR J9=1 TO L2 STEP 1
1340 LET K2=K2+1
1345 LET L3=L3+(N1+1)
1350 LET K2=INT(K2)
1355 LET L3=INT(L3)
1360 LET M(K2)=L3
1365 NEXT J9
1370 GOTO 1375
1375 LET I5=3
1380 LET I6=4
1385 LET I7=5
1390 LET N7=N8-1
1395 LET N7=INT(N7)
1400 FOR I9=1 TO N7 STEP 1
1405 LET I5=I5+3
1410 LET I6=I6+3
1415 LET I7=I7+3
1420 LET I8=I5-3
1425 LET H1=I6-3
1430 LET H2=I7-3
1435 IF ABS(Y(I5)-Y(I8))>=1E-3 THEN 1625
1440 IF ABS(Y(I6)-Y(H1))>=1E-3 THEN 1625
1445 IF ABS(Y(I7)-Y(H2))>=1E-3 THEN 1625
1450 NEXT I9
1455 IF L1<>1 THEN 1515
1460 IF K1<>0 THEN 1515
1465 IF ABS(P1)>=1E-7 THEN 1475
1470 LET F1=F2/COS(P1)
1475 IF ABS(P1)<1E-7 THEN 1485
```

```
1480 LET F1=F3/SIN(P1)
1485 LET F3=F1
1490 LET F2=F1
1495 LET P2=P1-3.14159265/4.0
1500 LET N9=1
1505 LET F3=F3*SIN(P2)
1510 LET F2=F2*COS(P2)
1515 GOTO 1520
1520 IF ABS(X(2))<=1E-3 THEN 1550
1525 LET S2=X(2)
1530 LET N3=INT(N3)
1535 FOR I9=1 TO N3 STEP 1
1540 LET X(I9)=X(I9)-S2
1545 NEXT I9
1550 GOTO 1555
1555 IF ABS(Y(3))<=1E-3 THEN 1580
1560 LET S7=Y(3)
1565 FOR I9=1 TO N3 STEP 1
1570 LET Y(I9)=Y(I9)-S7
1575 NEXT I9
1580 GOTO 1585
1585 LET R2=N8+1
1590 LET S3=SQR(2.0)
1595 FOR I9=1 TO N3 STEP 1
1600 LET X4=X(I9)
1605 LET Y4=Y(I9)
1610 LET Y(I9)=(H3*R2-X4+Y4)/S3
1615 LET X(I9)=(X4+Y4)/S3
1617 NEXT I9
1620 GOTO 1890
1625 GOTO 1630
1630 LET I5=3
1635 LET I6=4
1640 LET I7=5
1645 LET N7=N8-1
1650 LET N7=INT(N7)
1655 FOR I9=1 TO N7 STEP 1
1660 LET I5=I5+3
1665 LET I6=I6+3
1670 LET I7=I7+3
1675 LET I8=I5-3
1680 LET H1=I6-3
1685 LET H2=I7-3
1690 IF ABS(X(I5)-X(I8))>=1E-3 THEN 1890
1695 IF ABS(X(I6)-X(H1))>=1E-3 THEN 1890
1700 IF ABS(X(I7)-X(H2))>=1E-3 THEN 1890
1705 NEXT I9
1710 IF L1<>1 THEN 1770
1715 IF K1<>0 THEN 1770
1720 IF ABS(P1)>=1E-7 THEN 1730
1725 LET F1=F2/COS(P1)
1730 IF ABS(P1)<1E-7 THEN 1740
1735 LET F1=F3/SIN(P1)
1740 LET F3=F1
1745 LET F2=F1
1750 LET P2=P1+3.14159265/4.0
1755 LET N9=-1
1760 LET F3=F3*SIN(P2)
1765 LET F2=F2*COS(P2)
1770 GOTO 1775
1775 LET M2=N3-1
```

000061

```
1780 LET M2=INT(M2)
1785 IF ABS(Y(M2))<=1E-3 THEN 1815
1790 LET S4=Y(M2)
1795 LET N3=INT(N3)
1800 FOR I9=1 TO N3 STEP 1
1805 LET Y(I9)=Y(I9)-S4
1810 NEXT I9
1815 GOTO 1820
1820 IF ABS(X(3))<=1E-3 THEN 1845
1825 LET S5=X(3)
1830 FOR I9=1 TO N3 STEP 1
1835 LET X(I9)=X(I9)-S5
1840 NEXT I9
1845 GOTO 1850
1850 LET R2=M8+1
1855 LET S3=SQR(2.0)
1860 FOR I9=1 TO N3 STEP 1
1865 LET X4=X(I9)
1870 LET Y4=Y(I9)
1875 LET X(I9)=(H3*R2+X4-Y4)/S3
1880 LET Y(I9)=(X4+Y4)/S3
1885 NEXT I9
1890 GOTO 1895
1895 IF L1<>1 THEN 1945
1900 IF K1<>0 THEN 1945
1905 REM PRINT "CORDINATES OF JOINTS"
1910 REM PRINT "_____ __ _____"
1915 REM PRINT
1920 REM PRINT
1925 REM PRINT "JOINT                    X                Y"
1930 REM PRINT "NUMBER          COORDINATES          COORDINATES"
1935 REM PRINT "                     IN                 IN"
1940 REM PRINT
1945 REM LET N2=INT(N2)
1950 REM FOR J9=1 TO N2 STEP 1
1955 REM PRINT USING 1960,J9,A(J9),B(J9)
1960 REM : ###        ########.####          ########.####
1965 REM NEXT J9
1970 FILE : 1,"ZZ2"
1971 SETW :1 TO 1
1972 FOR I9=1 TO N3 STEP 1
1975 LET J9=I9
1980 IF L1<>1 THEN 1995
1985 IF K1<>0 THEN 1995
1990 WRITE :1,J9,X(J9),Y(J9)
1995 IF L1=1 THEN 2000
1998 READ :1,J9,X(J9),Y(J9)
1999 GOTO 2010
2000 IF K1=0 THEN 2010
2005 READ :1,J9,X(J9),Y(J9)
2010 NEXT I9
2015 GOTO 2020
2020 IF I1=1 THEN 2500
2400 FOR I9=1 TO 64 STEP 1
2405 LET X(I9)=0.0
2410 LET Y(I9)=0.0
2415 NEXT I9
2500 LET L5=N4+1
2505 LET L6=N4+3
2510 LET L7=2*N4+2
2515 LET L8=2*N4+4
```

000062

```
2520 LET L9=3*M4+2
2525 LET E1=3*M4+4
2530 LET E2=N3-2
2535 LET E3=N3-3
2540 LET E4=N3-4
2545 IF I1=1 THEN 3315
2550 LET X(2)=0.0
2555 LET Y(2)=2.0*U1
2560 LET E2=INT(E2)
2565 FOR I9=5 TO E2 STEP 3
2570 LET X(I9)=X(I9-3)+H3
2575 LET Y(I9)=Y(2)
2580 NEXT I9
2585 LET N3=INT(N3)
2590 LET X(N3)=X(N3-2)+H3
2595 LET Y(N3)=Y(2)
2600 LET X(1)=0.0
2605 LET Y(1)=U1
2610 LET E3=INT(E3)
2615 FOR I9=4 TO E3 STEP 3
2620 LET X(I9)=X(I9-3)+H3
2625 LET Y(I9)=U1
2630 NEXT I9
2635 LET X(N3-1)=X(N3-3)+H3
2640 LET Y(N3-1)=U1
2645 LET X(3)=H3
2650 LET Y(3)=0.0
2655 LET E4=INT(E4)
2660 FOR I9=6 TO E4 STEP 3
2665 LET X(I9)=X(I9-3)+H3
2670 LET Y(I9)=Y(3)
2675 NEXT I9
2680 IF I2<>0 THEN 2880
2685 LET L2=M4+2
2690 LET K2=-1
2695 LET L3=-1
2700 LET L2=INT(L2)
2705 FOR J9=1 TO L2 STEP 1
2710 LET K2=K2+2
2715 LET L3=L3+3
2720 IF J9<>L2 THEN 2735
2725 LET K2=K2-1
2730 LET L3=L3-1
2735 LET A(K2)=X(L3)
2740 LET B(K2)=Y(L3)
2745 NEXT J9
2750 LET K2=0
2755 LET L3=0
2760 LET N4=INT(N4)
2765 FOR J9=1 TO N4 STEP 1
2770 LET K2=K2+2
2775 LET L3=L3+3
2780 LET A(K2)=X(L3)
2785 LET B(K2)=Y(L3)
2790 NEXT J9
2795 LET L2=N4+1
2800 LET L2=INT(L2)
2805 FOR J9=1 TO L2 STEP 1
2810 LET M(J9)=J9
2815 NEXT J9
2820 LET K2=N4*3+2
```

```
2825 LET L3=N4*2+2
2830 LET L2=N4+2
2835 LET L4=2*N4+1
2840 LET L2=INT(L2)
2845 LET L4=INT(L4)
2850 FOR J9=L2 TO L4 STEP 1
2855 LET M(J9)=0
2860 LET N(J9,1)=K2+1
2865 LET N(J9,2)=L3+1
2870 NEXT J9
2875 GOTO 3135
2880 IF N1>0 THEN 2945
2885 LET L2=N4*4+4
2890 LET L2=INT(L2)
2895 FOR J9=1 TO L2 STEP 1
2900 LET A(J9)=X(J9)
2905 LET B(J9)=Y(J9)
2910 NEXT J9
2915 LET L2=4*M4+2
2920 LET L2=INT(L2)
2925 FOR J9=1 TO L2 STEP 1
2930 LET M(J9)=J9
2935 NEXT J9
2940 GOTO 3135
2945 LET K2=0
2950 LET L3=0
2955 LET N5=0
2960 LET N6=N1+1
2965 LET N3=INT(N3)
2970 FOR J9=1 TO N3 STEP 1
2975 LET L3=L3+1
2980 LET I4=INT(J9/3)*3
2985 IF J9<>I4 THEN 3035
2990 LET N5=N5+1
2995 LET N4=INT(N4)
3000 LET N6=INT(N6)
3005 FOR I9=1 TO N4 STEP N6
3010 IF N5=I9 THEN 3035
3015 NEXT I9
3020 LET I4=N3-1
3025 IF J9>=I4 THEN 3035
3030 GOTO 3050
3035 LET K2=K2+1
3040 LET A(K2)=X(L3)
3045 LET B(K2)=Y(L3)
3050 NEXT J9
3055 LET L2=3*N4+2
3060 LET L2=INT(L2)
3065 FOR J9=1 TO L2 STEP 1
3070 LET M(J9)=J9
3075 NEXT J9
3080 LET K2=3*N4+3-(N1+1)
3085 LET L3=3*N4+2
3090 LET L2=INT(N4/(N1+1))+1
3095 LET L2=INT(L2)
3100 FOR J9=1 TO L2 STEP 1
3105 LET K2=K2+(N1+1)
3110 LET L3=L3+1
3115 LET K2=INT(K2)
3120 LET L3=INT(L3)
3125 LET M(L3)=K2
```

```
3130 NEXT J9
3135 GOTO 3140
3140 IF L1<>1 THEN 3195
3145 IF K1<>0 THEN 3195
3150 FOR J9=1 TO 4 STEP 1
3152 PRINT
3154 NEXT J9
3155 PRINT "                              COORDINATES OF JOINTS"
3160 PRINT "                              ----------- -- ------"
3165 PRINT
3170 PRINT
3175 PRINT "                    JOINT              X                    Y"
3180 PRINT "                    NUMBER         COORDINATES          COORDINATES"
3185 PRINT "                                      IN                   IN"
3190 PRINT
3195 IF I2<>1 THEN 3210
3200 IF N1<>0 THEN 3210
3205 LET M2=N3
3210 IF I2<>0 THEN 3220
3215 LET M2=2*M4+2
3220 IF I2<>1 THEN 3235
3225 IF N1<=0 THEN 3235
3230 LET M2=N3-(M4-(INT(M4/(N1+1))+1))
3235 LET M2=INT(M2)
3240 FOR J9=1 TO M2 STEP 1
3245 IF L1<>1 THEN 3265
3250 IF K1<>0 THEN 3265
3255 PRINT USING 3260,J9,A(J9),B(J9)
3260 :                   ###         ########.##              ########.##
3265 NEXT J9
3270 LET R3=N8+1
3275 LET S6=SQR(2.0)
3280 LET M3=INT(M3)
3285 FOR I9=1 TO M3 STEP 1
3290 LET X4=X(I9)
3295 LET Y4=Y(I9)
3300 LET Y(I9)=(H3*R3-X4+Y4)/S6
3305 LET X(I9)=(X4+Y4)/S6
3310 NEXT I9
3315 GOTO 3320
3320 REM
3325 REM MEMBER DESIGNATIONS AND PROPERTIES
3330 REM COMPUTATION OF MEMBER ENDS AND PROPERTIES
3335 REM
3340 LET J(1)=2
3345 LET K(1)=5
3350 LET C(1)=A2
3355 LET I(1)=R4
3360 LET E(1)=E5
3365 LET L5=INT(L5)
3370 FOR I9=2 TO L5 STEP 1
3375 LET J(I9)=K(I9-1)
3380 LET K(I9)=J(I9)+3
3385 IF I9<>M4+1 THEN 3395
3390 LET K(I9)=J(I9)+2
3395 LET C(I9)=A2
3400 LET I(I9)=R4
3405 LET E(I9)=E5
3410 NEXT I9
3415 LET J(M4+2)=1
3420 LET K(M4+2)=4
```

000065

```
3425 LET C(M4+2)=A3
3430 LET I(M4+2)=R5
3435 LET E(M4+2)=E6
3440 LET L6=INT(L6)
3445 LET L7=INT(L7)
3450 FOR I9=L6 TO L7 STEP 1
3455 LET J(I9)=K(I9-1)
3460 LET K(I9)=J(I9)+3
3465 IF I9<>2*M4+2 THEN 3475
3470 LET K(I9)=J(I9)+2
3475 LET C(I9)=A3
3480 LET I(I9)=R5
3485 LET E(I9)=E6
3490 NEXT I9
3495 LET J(2*M4+3)=4
3500 LET K(2*M4+3)=5
3505 LET C(2*M4+3)=A4
3510 LET I(2*M4+3)=R6
3515 LET E(2*M4+3)=E7
3520 LET L8=INT(L8)
3525 LET L9=INT(L9)
3530 FOR I9=L8 TO L9 STEP 1
3535 LET J(I9)=J(I9-1)+3
3540 LET K(I9)=J(I9)+1
3545 LET C(I9)=A4
3550 LET I(I9)=R6
3555 LET E(I9)=E7
3560 NEXT I9
3565 LET J(3*M4+3)=3
3570 LET K(3*M4+3)=4
3575 LET C(3*M4+3)=A5
3580 LET I(3*M4+3)=R7
3585 LET E(3*M4+3)=E8
3590 LET E1=INT(E1)
3595 FOR I9=E1 TO M3 STEP 1
3600 LET J(I9)=J(I9-1)+3
3605 LET K(I9)=J(I9)+1
3610 LET C(I9)=A5
3615 LET I(I9)=R7
3620 LET E(I9)=E8
3625 NEXT I9
3630 FOR J9=1 TO M3 STEP 1
3635 LET L(J9)=0
3640 LET I9=J9
3645 IF J(I9)-K(I9)<=0 THEN 3665
3650 LET M4=J(I9)
3655 LET J(I9)=K(I9)
3660 LET K(I9)=M4
3665 LET J2=K(I9)
3670 LET J3=J(I9)
3675 LET X5=X(J2)-X(J3)
3680 LET Y5=Y(J2)-Y(J3)
3685 LET H(I9)=SQR(X5↑2+Y5↑2)
3690 LET G(I9)=X5/H(I9)
3695 LET F(I9)=Y5/H(I9)
3700 NEXT J9
3705 IF I2<>1 THEN 3720
3710 IF M1<>0 THEN 3720
3715 LET M4=4*M4+2
3720 IF I2<>0 THEN 3730
3725 LET M4=2*M4+1
```

```
3730 IF I2<>1 THEN 3745
3735 IF N1<=0 THEN 3745
3740 LET M4=4*M4+2-(M4-(INT(M4/(N1+1)))+1))
3745 IF L1<>1 THEN 3795
3750 IF K1<>0 THEN 3795
3752 GOSUB 4415
3755 PRINT "                        MEMBER DESIGNATIONS AND PROPERTIES"
3760 PRINT "                        ------ ------------ --- ----------"
3765 PRINT
3770 PRINT
3775 PRINT " MEMBER          NEAR          FAR"
3780PRINT" NUMBER          END           END          AREA         INERTIA          LENGTH"
3785 PRINT "                                             IN**2         IN**4             IN"
3790 PRINT
3795 LET M4=INT(M4)
3800 FOR J9=1 TO M4 STEP 1
3805 IF I2=1 THEN 3950
3810 IF M(J9)>0 THEN 3865
3815 LET H5=N(J9,1)
3820 LET H6=N(J9,2)
3825 LET O(J9)=H(H5)+H(H6)
3830 LET U(J9)=C(H5)
3835 LET V(J9)=I(H5)
3840 LET P(J9)=G(H5)
3845 LET Q(J9)=F(H5)
3850 LET R(J9)=(J9-(N4+1))*2
3855 LET S(J9)=(J9-(N4+1))*2+1
3860 GOTO 3925
3865 LET H7=M(J9)
3870 LET H7=INT(H7)
3875 LET O(J9)=H(H7)
3880 LET U(J9)=C(H7)
3885 LET V(J9)=I(H7)
3890 LET P(J9)=G(H7)
3895 LET Q(J9)=F(H7)
3900 LET R(J9)=2*J9-1
3905 LET S(J9)=2*J9+1
3910 LET I4=N4+1
3915 IF J9<>I4 THEN 3925
3920 LET S(J9)=S(J9)-1
3925 IF L1<>1 THEN 3945
3930 IF K1<>0 THEN 3945
3935 PRINT USING 3940,J9,R(J9),S(J9),U(J9),V(J9),O(J9)
3940 : ###      ######.##      #####.##      ######.##      ######.##      ######.##
3945 GOTO 4135
3950 IF N1=0 THEN 4120
3951 IF L1<>1 THEN 4135
3952 IF K1<>0 THEN 4135
3955 LET H7=M(J9)
3960 LET H7=INT(H7)
3965 LET U(J9)=C(H7)
3970 LET V(J9)=I(H7)
3975 LET O(J9)=H(H7)
3980 LET P(J9)=G(H7)
3985 LET Q(J9)=F(H7)
3990 LET J1=INT(J(H7)/3)-1
3995 LET J4=INT(J1/(N1+1))
4000 LET J5=J4*(N1+1)
4005 LET J6=J1-J5
4010 LET J7=J4*N1+J6
4015 LET R(J9)=J(H7)-J7
```

```
4020 LET J1=INT(K(H7)/3)-1
4025 LET J4=INT(J1/(N1+1))
4030 LET J5=J4*(N1+1)
4035 LET J6=J1-J5
4040 LET J7=J4*N1+J6
4045 LET S(J9)=K(H7)-J7
4050 IF J(H7)<>1 THEN 4060
4055 LET R(J9)=1
4060 IF J(H7)<>2 THEN 4070
4065 LET R(J9)=2
4070 LET T(1)=3*N4+4
4075 IF K(H7)<>T(1) THEN 4085
4080 LET S(J9)=S(J9)+1
4085 LET T(1)=T(1)-1
4090 IF K(H7)<>T(1) THEN 4100
4095 LET S(J9)=S(J9)+1
4100 IF L1<>1 THEN 4115
4105 IF K1<>0 THEN 4115
4110 PRINT USING 3940,J9,R(J9),S(J9),U(J9),V(J9),O(J9)
4115 GOTO 4135
4120 IF L1<>1 THEN 4135
4125 IF K1<>0 THEN 4135
4130 PRINT USING 3940,J9,J(J9),K(J9),C(J9),I(J9),H(J9)
4135 NEXT J9
4140 REM
4145 REM JOINT RESTRAINT LIST,CUMULATIVE RESTRAINT LIST
4150 REM RL=JOINT RESTRAINT LIST.. RL(3K-2),RL(3K-1),RL(3K)
4155 REM IF RSTRT EXISTS 1 OTHERWISE 0
4160 REM CUMULATIVE RESTRAINT LIST
4165 REM
4170 LET M9=INT(M9)
4175 FOR I9=1 TO M9 STEP 1
4180 LET O(I9)=0
4185 LET W(I9)=0
4187 NEXT I9
4190 LET T(3)=N3-4
4195 LET T(3)=INT(T(3))
4200 FOR J9=3 TO T(3) STEP 3
4205 LET O(J9*3-2)=1
4210 LET O(J9*3-1)=1
4215 NEXT J9
4220 LET W(1)=O(1)
4225 LET M9=INT(M9)
4230 FOR K9=2 TO M9 STEP 1
4235 LET W(K9)=W(K9-1)+O(K9)
4237 NEXT K9
4240 REM
4245 REM STRUCTURE STIFFNESS MATRIX
4250 REM
4255 REM J1,J2,J3=INDEXES FOR DISPLACEMENT AT J END OF MEMBER
4260 REM K1,K2,K3=INDEXES FOR DISPLACEMENT AT K END OF MEMBER
4265 REM
4270 LET N3=INT(N3)
4275 FOR J9=5 TO N3 STEP 1
4280 LET T(4)=INT((J9-2)/3)*3
4285 LET T(5)=J9-2
4290 IF T(4)<>T(5) THEN 4335
4295 LET T(6)=Y(J9)-Y(J9-2)
4300 LET T(7)=X(J9)-X(J9-2)
4305 IF T(6)<>0.0 THEN 4320
4310 LET Z(J9)=3.14159265/2.0
```

```
4315 GOTO 4325
4320 LET Z(J9)=ATN(T(7)/T(6))
4325 LET Z(J9-1)=Z(J9)
4330 LET Z(J9-2)=Z(J9)
4335 NEXT J9
4340 LET T(6)=Y(2)-Y(1)
4345 LET T(7)=X(2)-X(1)
4350 IF T(6)<>0.0 THEN 4365
4355 LET Z(2)=3.14159265/2.0
4360 GOTO 4370
4365 LET Z(2)=ATN(T(7)/T(6))
4370 LET Z(1)=Z(2)
4375 LET T(6)=Y(N3)-Y(N3-1)
4380 LET T(7)=X(N3)-X(N3-1)
4385 IF T(6)<>0.0 THEN 4400
4390 LET Z(N3)=3.14159265/2.0
4395 GOTO 4405
4400 LET Z(N3)=ATN(T(7)/T(6))
4405 LET Z(N3-1)=Z(N3)
4410 GOTO 4514
4415 FOR I9=1 TO 4 STEP 1
4425 PRINT
4435 NEXT I9
4445 RETURN
4500 REM -----------------------------------------------
4505 REM FILE OUTPUT
4510 REM ------------- ----  --------------------------
4514 FILE : 1,"COM7"
4515 SETW :1 TO 1
4520 WRITE :1,N4,N3,N9
4525 FOR I9=1 TO N3 STEP 1
4530 WRITE :1,J(I9),K(I9),C(I9),I(I9),H(I9)
4535 NEXT I9
4540 FOR I9=1 TO N3 STEP 1
4545 WRITE :1,E(I9),G(I9),F(I9)
4550 NEXT I9
4555 FOR I9=1 TO N9 STEP 1
4560 WRITE :1,O(I9),W(I9),D(I9)
4565 NEXT I9
4570 WRITE :1,N4,I2,N8,K3,N1
4574 FILE : 1,"CO6"
4575 SETW :1 TO 1
4580 WRITE :1,N9,F3,F2,Q2,Q1,Q3,D3
4582 WRITE :1,N3
4585 FOR I9=1 TO N3 STEP 1
4590 WRITE :1,Z(I9)
4594 NEXT I9
4595 FILE : 1,"POINT2"
4596 SETW :1 TO 1
4597 LET U3=0.0
4598 WRITE :1,U3
4599 FILE : 1,"P"
4600 SETW :1 TO 1
4601 WRITE :1,T5,N9,T6,T7,T8
4602 REM -----------------------------------------------
4603 REM PRINT USING 4604,T5,N9,T6,T7,T8
4604 : U6=### NTHIN=#### NZS=#### ISLDPT=###### F(I)=####.####
4605 REM CHAIN STATEMENT
4610 CHAIN "*MATRIX"
4615 REM -----------------------------------------------
5000 END
```

END OF LISTING

```
0005 REM ***********************************************************************
0010 REM SUBROUTINE DIAG
0015 REM ***********************************************************************
0016 DISP "          FRAME DIAGRAM"
0020 DCL 4N$()
0025 FILES DRAW
0030 SETW :1 TO 1
0035 REM
0040 READ :1,N1,N2,I3
0045 REM
0050 REM ----------------------------------------------------------------------
0055 REM DIMENSIONING OF ARRAYS
0060 DIM A(12),C(12),D(11),G(11),H(11),N$(23,90)
0065 REM ----------------------------------------------------------------------
0070 FOR I9=1 TO 10 STEP 1
0080 PRINT
0090 NEXT I9
0500 LET L1=INT((N1-2)/5)+1
0505 FOR I=1 TO L1 STEP 1
0510 IF I<>1 THEN 565
0515 PRINT TAB(23);"FRAME DIAGRAM (NOT DRAWN TO SCALE)"
0520 PRINT TAB(23);"_____ _____ ____ _____ __ _____"
0525 PRINT
0530 PRINT
0535 PRINT "     N=MEMBER NUMBER"
0540 PRINT "    *N*=JOINT NUMBER"
0545 PRINT "    (N)=SPRING NUMBER"
0550 PRINT
0555 PRINT
0560 GOTO 590
0565 IF INT(I/2*2)=I THEN 575
0570 GOTO 590
0575 FOR I9=1 TO 4 STEP 1
0580 PRINT
0585 NEXT I9
0590 LET I1=5*I-4
0595 LET I2=I1+5
0600 IF I2<=N1 THEN 610
0605 LET I2=N1
0610 LET N3=I2-I1+1
0615 IF I3=0 THEN 880
0620 IF N2<>0 THEN 740
0625 LET K=0
0630 FOR J=I1 TO I2 STEP 1
0635 LET K=K+1
0640 LET A(K)=2+3*(J-1)
0645 LET B(K)=A(K)-1
0650 LET C(K)=A(K)+1
0655 LET D(K)=J
0660 LET E(K)=J+N1+1
0665 LET F(K)=J+2*N1+2
0670 LET G(K)=J+3*N1+2
0675 LET H(K)=J+N1
```

000070

```
0680 LET L(K)=J
0685 NEXT J
0690 LET A(K+1)=A(K)+3
0695 LET A(K+2)=A(K)+6
0700 LET B(K+1)=B(K)+3
0705 LET B(K+2)=B(K)+6
0710 LET D(K+1)=D(K)+1
0715 LET E(K+1)=E(K)+1
0720 IF I2<>N1 THEN 950
0725 LET A(K+2)=A(K+2)-1
0730 LET B(K+2)=B(K+2)-1
0735 GOTO 950
0740 LET K=0
0745 FOR J=I1 TO I2 STEP 1
0750 LET K=K+1
0755 LET A(K)=2+3*(J-1)-(J-1-INT((J+N2-1)/(N2+1)))
0760 LET B(K)=A(K)-1
0765 LET C(K)=0
0770 LET D(K)=J
0775 LET E(K)=J+N1+1
0780 LET F(K)=J+2*N1+2
0785 LET G(K)=0
0790 LET H(K)=J+INT(N1/(N2+1))+1
0795 LET L(K)=0
0800 LET I4=J-1
0805 LET I5=INT((J-1)/(N2+1))*(N2+1)
0810 IF I4<>I5 THEN 830
0815 LET C(K)=A(K)+1
0820 LET G(K)=J+3*N1+2-(J-INT((J+N2)/(N2+1)))
0825 LET L(K)=J-(J-INT((J+N2)/(N2+1)))
0830 NEXT J
0835 LET J=I2+1
0840 LET A(K+1)=2+3*(J-1)-(J-1-INT((J+N2-1)/(N2+1)))
0845 LET B(K+1)=A(K+1)-1
0850 LET D(K+1)=J
0855 LET E(K+1)=J+N1+1
0860 LET J=I2+2
0865 LET A(K+2)=2+3*(J-1)-(J-1-INT((J+N2-1)/(N2+1)))
0870 LET B(K+2)=A(K+2)-1
0875 GOTO 950
0880 LET K=0
0885 FOR J=I1 TO I2 STEP 1
0890 LET K=K+1
0895 LET A(K)=2*(J-1)+1
0900 LET C(K)=2*J
0905 LET M(K)=J
0910 LET P(K)=J+N1+1
0915 LET Q(K)=J
0920 NEXT J
0925 LET A(K+1)=A(K)+2
0930 LET A(K+2)=A(K)+4
0935 LET M(K+1)=M(K)+1
0940 IF N1<>I2 THEN 950
0945 LET A(K+2)=A(K+2)-1
0950 FOR J=1 TO 23 STEP 1
0955 FOR K=1 TO 80 STEP 1
0960 LET M$(J,K)=" "
0965 NEXT K
0970 NEXT J
0975 IF I3=0 THEN 1520
0980 LET L2=N3+2
```

```
0985 FOR J=1 TO L2 STEP 1
0990 LET M1=J
0995 LET N4=A(J)
1000 LET L3=1
1005 LET I6=10*(M1-1)+1
1010 LET I7=3
1015 REM ----------------------------------------
1020 GOSUB 1850
1025 REM ----------------------------------------
1030 NEXT J
1035 LET L2=(N3+1)*10+3
1040 FOR J=3 TO L2 STEP 1
1045 LET N$(2,J)="X"
1050 LET N$(12,J)="X"
1055 NEXT J
1060 FOR J=1 TO N3 STEP 1
1065 LET K=10*J+3
1070 FOR L9=3 TO 11 STEP 1
1075 LET N$(L9,K)="X"
1080 NEXT L9
1085 FOR L9=13 TO 22 STEP 1
1090 LET N$(L9,K)="X"
1095 NEXT L9
1100 NEXT J
1105 LET L2=N3+1
1110 FOR J=1 TO L2 STEP 1
1115 LET M1=J
1120 LET N4=D(J)
1125 LET L3=3
1130 LET I6=10*(M1-1)+6
1135 LET I7=1
1140 REM ----------------------------------------
1145 GOSUB 1850
1150 REM ----------------------------------------
1155 NEXT J
1160 FOR J=1 TO N3 STEP 1
1165 LET M1=J
1170 LET N4=F(J)
1175 LET L3=7
1180 LET I6=10*M1+4
1185 LET I7=2
1190 REM ----------------------------------------
1195 GOSUB 1850
1200 REM ----------------------------------------
1205 LET N4=H(J)
1210 LET I6=10*(M1-1)+8
1215 LET I7=5
1220 REM ----------------------------------------
1225 GOSUB 1850
1230 REM ----------------------------------------
1235 NEXT J
1240 LET L2=N3+2
1245 FOR J=1 TO L2 STEP 1
1250 LET M1=J
1255 LET N4=B(J)
1260 LET L3=11
1265 LET I6=10*(M1-1)+4
1270 LET I7=4
1275 REM ----------------------------------------
1280 GOSUB 1850
1285 REM ----------------------------------------
```

```
1290 NEXT J
1295 LET L2=N3+1
1300 FOR J=1 TO L2 STEP 1
1305 LET M1=J
1310 LET N4=E(J)
1315 LET L3=13
1320 LET I6=10*(M1-1)+6
1325 LET I7=1
1330 REM -------------------------------------------------
1335 GOSUB 1850
1340 REM -------------------------------------------------
1345 NEXT J
1350 FOR J=1 TO N3 STEP 1
1355 LET M1=J
1360 LET N4=G(J)
1365 LET L3=17
1370 LET I6=10*M1+4
1375 LET I7=2
1380 REM -------------------------------------------------
1385 GOSUB 1850
1390 REM -------------------------------------------------
1395 LET N4=L(J)
1400 LET I6=10*(M1-1)+8
1405 LET I7=5
1410 REM -------------------------------------------------
1415 GOSUB 1850
1420 REM -------------------------------------------------
1425 LET N4=C(J)
1430 LET L3=23
1435 LET I6=10*M1+1
1440 LET I7=3
1445 REM -------------------------------------------------
1450 GOSUB 1850
1455 REM -------------------------------------------------
1460 NEXT J
1465 IF N2=0 THEN 1795
1470 LET K=0
1475 FOR J=I1 TO I2 STEP 1
1480 LET K=K+1
1485 IF C(K)<>0 THEN 1510
1490 LET L9=10*K+3
1495 FOR M9=13 TO 22 STEP 1
1500 LET N$(M9,L9)=" "
1505 NEXT M9
1510 NEXT J
1515 GOTO 1795
1520 LET L2=N3+2
1525 FOR J=1 TO L2 STEP 1
1530 LET M1=J
1535 LET N4=A(J)
1540 LET L3=1
1545 LET I6=10*(M1-1)+1
1550 LET I7=3
1555 REM -------------------------------------------------
1560 GOSUB 1850
1565 REM -------------------------------------------------
1570 NEXT J
1575 LET L2=(N3+1)*10+3
1580 FOR J=3 TO L2 STEP 1
1585 LET N$(2,J)="X"
1590 NEXT J
```

```
1595 FOR J=1 TO N3 STEP 1
1600 LET K=10*J+3
1605 FOR L9=3 TO 22 STEP 1
1610 LET N$(L9,K)="X"
1615 NEXT L9
1620 NEXT J
1625 LET L2=N3+1
1630 FOR J=1 TO L2 STEP 1
1635 LET M1=J
1640 LET N4=M(J)
1645 LET L3=3
1650 LET I6=10*(M1-1)+6
1655 LET I7=1
1660 REM ------------------------------------------------------
1665 GOSUB 1850
1670 REM ------------------------------------------------------
1675 NEXT J
1680 FOR J=1 TO N3 STEP 1
1685 LET M1=J
1690 LET N4=P(J)
1695 LET L3=12
1700 LET I6=10*M1+4
1705 LET I7=2
1710 REM ------------------------------------------------------
1715 GOSUB 1850
1720 REM ------------------------------------------------------
1725 LET N4=Q(J)
1730 LET I6=10*(M1-1)+8
1735 LET I7=5
1740 REM ------------------------------------------------------
1745 GOSUB 1850
1750 REM ------------------------------------------------------
1755 LET N4=C(J)
1760 LET L3=23
1765 LET I6=10*M1+1
1770 LET I7=3
1775 REM ------------------------------------------------------
1780 GOSUB 1850
1785 REM ------------------------------------------------------
1790 NEXT J
1795 FOR J=1 TO 23 STEP 1
1800 PRINT N$(J,1);N$(J,2);N$(J,3);N$(J,4);N$(J,5);N$(J,6);N$(J,7);N$(J,8);
1801 PRINT N$(J,9);N$(J,10);N$(J,11);N$(J,12);N$(J,13);N$(J,14);N$(J,15);
1802 PRINT N$(J,16);N$(J,17);N$(J,18);N$(J,19);N$(J,20);N$(J,21);N$(J,22);
1803 PRINT N$(J,23);N$(J,24);N$(J,25);N$(J,26);N$(J,27);N$(J,28);N$(J,29);
1804 PRINT N$(J,30);N$(J,31);N$(J,32);N$(J,33);N$(J,34);N$(J,35);N$(J,36);
1805 PRINT N$(J,37);N$(J,38);N$(J,39);N$(J,40);N$(J,41);N$(J,42);N$(J,43);
1806 PRINT N$(J,44);N$(J,45);N$(J,46);N$(J,47);N$(J,48);N$(J,49);N$(J,50);
1807 PRINT N$(J,51);N$(J,52);N$(J,53);N$(J,54);N$(J,55);N$(J,56);N$(J,57);
1808 PRINT N$(J,58);N$(J,59);N$(J,60);N$(J,61);N$(J,62);N$(J,63);N$(J,64);
1809 PRINT N$(J,65);N$(J,66);N$(J,67);N$(J,68);N$(J,69);N$(J,70);N$(J,71);
1810 PRINT N$(J,72);N$(J,73);N$(J,74);N$(J,75);N$(J,76);N$(J,77);N$(J,78);
1811 PRINT N$(J,79);N$(J,80)
1815 NEXT J
1817 NEXT I
1820 GOTO 2300
1825 REM
1830 REM
1835 REM ******************************************************************
1840 REM SUBROUTINE ALIGN
1845 REM ******************************************************************
```

```
1850 LET R$(1)="1"
1855 LET R$(2)="2"
1860 LET R$(3)="3"
1865 LET R$(4)="4"
1870 LET R$(5)="5"
1875 LET R$(6)="6"
1880 LET R$(7)="7"
1885 LET R$(8)="8"
1890 LET R$(9)="9"
1895 LET R$(10)="0"
1900 FOR I9=1 TO 5 STEP 1
1905 LET S$(I9)=" "
1910 NEXT I9
1915 IF N4=0 THEN 2270
1920 LET T(1)=INT(N4/100)
1925 LET T(2)=INT((N4-T(1)*100)/10)
1930 LET T(3)=N4-T(1)*100-T(2)*10
1935 FOR I9=1 TO 3 STEP 1
1940 IF T(I9)<>0 THEN 1950
1945 LET T(I9)=10
1950 NEXT I9
1955 FOR I9=1 TO 3 STEP 1
1960 LET I8=T(I9)
1965 LET U$(I9)=R$(I8)
1970 NEXT I9
1975 LET N5=3
1980 FOR I9=1 TO 3 STEP 1
1985 IF U$(I9)<>R$(10) THEN 2010
1990 LET U$(I9)=" "
1995 LET N5=N5-1
2000 NEXT I9
2010 FOR I9=1 TO 3 STEP 1
2015 LET S$(I9+1)=U$(I9)
2020 NEXT I9
2025 ON I7 GOTO 2080,2080,2030,2030,2055
2030 LET G1=4-N5
2035 LET S$(G1)="*"
2040 LET S$(5)="*"
2045 LET N5=N5+2
2050 GOTO 2100
2055 LET G1=4-N5
2057 LET S$(G1)="("
2060 LET S$(G1)="("
2065 LET S$(5)=")"
2070 LET N5=N5+2
2075 GOTO 2100
2080 LET S$(5)=S$(4)
2085 LET S$(4)=S$(3)
2090 LET S$(3)=S$(2)
2095 LET S$(2)=" "
2100 ON I7 GOTO 2105,2170,2105,2170,2270
2105 ON N5 GOTO 2110,2125,2145,2270,2270
2110 LET S$(3)=S$(5)
2115 LET S$(5)=" "
2120 GOTO 2270
2125 LET S$(3)=S$(4)
2130 LET S$(4)=S$(5)
2135 LET S$(5)=" "
2140 GOTO 2270
2145 LET S$(2)=S$(3)
2150 LET S$(3)=S$(4)
```

```
2155 LET S$(4)=S$(5)
2160 LET S$(5)=" "
2165 GOTO 2270
2170 ON N5 GOTO 2175,2190,2215,2245,2270
2175 LET S$(1)=S$(5)
2180 LET S$(5)=" "
2185 GOTO 2270
2190 LET S$(1)=S$(4)
2195 LET S$(2)=S$(5)
2200 LET S$(4)=" "
2205 LET S$(5)=" "
2210 GOTO 2270
2215 LET S$(1)=S$(3)
2220 LET S$(2)=S$(4)
2225 LET S$(3)=S$(5)
2230 LET S$(4)=" "
2235 LET S$(5)=" "
2240 GOTO 2270
2245 LET S$(1)=S$(2)
2250 LET S$(2)=S$(3)
2255 LET S$(3)=S$(4)
2260 LET S$(4)=S$(5)
2265 LET S$(5)=" "
2270 LET G2=I6-1
2275 FOR I9=1 TO 5 STEP 1
2280 LET G2=G2+1
2285 LET N$(L3,G2)=S$(I9)
2290 NEXT I9
2295 RETURN
2300 DISP "INIT. SYS. FOR MAT OPT,RUN *PIL"
2305 FOR I9=1 TO 3 STEP 1
2310 FOR K9=1 TO 100 STEP 1
2315 BEEP
2320 NEXT K9
2325 DELAY 6
2330 NEXT I9
2335 END

END OF LISTING




OLD *S3363
LIST
FILE    *S3363


0005 REM *********************************************************************
0010 REM SUBROUTINE S3363
0015 REM *********************************************************************
0020 REM
0025 REM
0030 REM --------------------------------------------
0035 REM FILE INPUT
0040 REM --------------------------------------------------------
0045 FILES COMM2;COMM5;COMM7                                    000076
0050 SETW :1 TO 1
0055 MAT READ :1,M(10,3),Q(6,1),V(6,1),H(10,3),U(6,1),G(6,1),L(6,6),S(6,6)
0060 READ :1,I4,I3,N1,N2,K5,K3,N3,E1,G3,A1
0065 READ :1,A3,A6,D1,D2,A5,B1,A4,K,Z,U1,K8,Z4,Z2,Z3
0066 FOR I9=1 TO K8 STEP 1
```

```
0067 READ :1,F(I9)
0068 NEXT I9
0070 FOR I9=1 TO K8 STEP 1
0075 READ :1,X(I9),Y(I9),N(I9),P(I9)
0080 NEXT I9
0085 DISP USING 87,K
0087 :              PILE ###
0090 REM --------------------------------------------------------------
0095 REM DIMENSIONING OF ARRAYS
0100 REM --------------------------------------------------------------
0105 DIM A(6,6),B(6,6),C(6,6),D(6,6),E(6,6),R(6,6),L(6,6),T(6,6),S(6,6)
0110 DIM Q(6,1),V(6,1),U(6,1),G(6,1),X(20),Y(20),N(20),P(20),W(6,1)
0115 DIM M(10,3),H(10,3),O(36),J(36),I(36)
0137 REM
0140 REM --------------------------------------------------------------
0145 REM LOGIC INITIALIZATION,RECOGNITION,AND REORGANIZATION
0150 REM --------------------------------------------------------------
0151 LET I5=1
0152 LET I6=1
0155 LET L1=0
0160 LET L2=0
0165 IF I3-10000<=0 THEN 180
0170 LET I3=I3-10000
0175 LET L2=1
0180 LET J1=I4
0185 IF I4-362<>0 THEN 240
0235 LET J1=2
0240 IF I3-1>0 THEN 4054
0245 LET M1=0
0250 LET I1=0
0255 REM LET K5=K5+1
0260 REM --------------------------------------------------------------
0265 REM INPUT VERIFICATION
0270 REM --------------------------------------------------------------
0275 IF J1-2<>0 THEN 1520
0280 IF L2-1<>0 THEN 305
0282 GOSUB 4595
0285 PRINT "WARNING---"
0290 PRINT "LATERAL LOADS HAVE BEEN INPUT WITHOUT A PILE WITH A BATTER"
0295 PRINT "COMPONENT IN THAT DIRECTION-LATERAL LOADS HAVE BEEN SET TO ZERO"
0300 PRINT "EXECUTION CONTINUES"
0305 GOSUB 4595
0306 GOSUB 4595
0307 PRINT TAB(8);"****************************************************";
0308 PRINT "********"
0310 PRINT TAB(8);"*          THIRD LEVEL STRUCTURAL DATA OUTPUT FROM S3363";
0311 PRINT TAB(72);"*"
0315 PRINT TAB(8);"*                  (3-DIMENSIONAL PILE ANALYSIS)";
0316 PRINT TAB(72);"*"
0320 PRINT TAB(8);"****************************************************";
0321 PRINT "********"
0325 GOSUB 4595
0330 PRINT "A. INPUT VERIFICATION OF STRUCTURAL DATA"
0335 PRINT "__ _____ _____ __ _____ ____"
0340 PRINT
0345 PRINT "TECHNIQUE LOGIC (NLOG)=";N1
0350 PRINT "PILE FICITY LOGIC (NGMM)=";N2
0355 PRINT "PILE/AXIAL PARTICIPATION AND SHAPE FACTOR (KTL)=";K5
0360 PRINT "VERTICAL PILE LOGIC (KRSD)=";K3
0365 PRINT
0370 PRINT "NUMBER OF PILES";K
```

000077

```
0375 PRINT "MODULUS OF ELASTICITY=";E1
0380 PRINT "TORSIONAL MODULUS=";G3
0385 PRINT "SUBGRADE MODULUS=";A1
0389 GOSUB 4595
0390 PRINT TAB(32);"PILE DATA"
0391 PRINT
0392 PRINT TAB(3);"PILE";TAB(11);"VER.";TAB(20);"HOR.";TAB(31);"X";TAB(41);"Y";
0393 PRINT TAB(51);"Z";TAB(59);"PILE";TAB(67);"PILE"
0394 PRINT TAB(3);"NO.";TAB(11);"SLOPE";TAB(20);"SLOPE";TAB(29);"COOR.";TAB(39);
0395 PRINT "COOR.";TAB(49);"COOR.";TAB(58);"LENGTH";TAB(67);"ANGLE"
0410 FOR I9=1 TO K STEP 1
0415 LET T1=N(I9)
0420 LET T2=P(I9)
0425 LET T3=X(I9)
0430 LET T4=Y(I9)
0435 LET T5=Z
0440 LET T6=A3
0445 LET T7=A6
0450 PRINT USING 455,I9,T1,T2,T3,T4,T5,T6,T7
0455 : ###    ####.##  ####.##  ###.###  ####.###  ####.###  ####.##  ###.###
0460 NEXT I9
0465 GOSUB 4595
0470 PRINT TAB(28);"PILE DATA (CONT.)"
0471 PRINT
0472 PRINT TAB(3);"PILE";TAB(42);"WIDTH";TAB(53);"WIDTH";TAB(65);"CANT."
0473 PRINT TAB(3);"NO.";TAB(12);"I-XX";TAB(22);"I-YY";TAB(32);"I-ZZ";TAB(45);
0474 PRINT "XX";TAB(55);"YY";TAB(65);"LENGTH"
0485 FOR I9=1 TO K STEP 1
0490 LET T1=A5
0495 LET T2=B1
0500 LET T3=A4
0505 LET T4=D1
0510 LET T5=D2
0515 LET T6=F(I9)
0520 PRINT USING 522,I9,T1,T2,T3,T4,T5,T6
0522 : ###    ####.####  ####.####  ####.####  ####.####  ####.####    ####.####
0524 NEXT I9
0525 IF N3<=0 THEN 560
0530 GOSUB 4595
0535 PRINT TAB(29);"DEFLECTION TEST"
0537 PRINT
0540 PRINT TAB(5);"POINT";TAB(28);"X";TAB(44);"Y";TAB(61);"Z"
0545 PRINT TAB(4);"NUMBER";TAB(24);"COORDINATE";TAB(40);"COORDINATE";TAB(57);
0546 PRINT "COORDINATE"
0547 FOR I9=1 TO N3 STEP 1
0551 PRINT USING 553,I9,M(I9,1),M(I9,2),M(I9,3)
0553 :      ###                ####.###          ####.###          ####.###
0557 NEXT I9
0560 PRINT
0561 PRINT
0562 PRINT
0565 PRINT
0566 PRINT "NUMBER OF SAMPLE POINTS=";N3
0567 GOSUB 4595
0570 GOTO 1520
0575 REM ----------------------------------------------------------------
0580 REM RE-INITIALIZATION FOR EXCEPTIONAL CASES
0585 REM ----------------------------------------------------------------
0590 IF A1=0 THEN 615
0595 PRINT "AN IMPOSSIBLE CONFIGURATION HAS BEEN ENCOUNTERED"
0600 PRINT "PROGRAM ANALYST MUST BE NOTIFIED"
```

```
0605 PRINT "EXECUTIOY HAS BEEN TERMINATED"
0610 GOTO 9999
0615 LET A1=0.00001728*10.0↑I1
0620 LET A2=A1*0.578703703+0.00005
0625 LET L1=1
0630 PRINT USING 635,A2
0635 : A SUBGRADE MODULUS OF ####.#### PCI HAS BEEN INSERTED
0640 IF D1>0 THEN 1520
0645 FOR I9=1 TO K STEP 1
0650 LET D1=0.5
0655 LET D2=0.5
0660 LET A5=B1=0.00482253086
0665 NEXT I9
0670 REM ----------------------------------------------------------
0675 REM INITIALIZATION OF MATRICES
0680 REM ----------------------------------------------------------
1520 FOR I=1 TO 6 STEP 1
1530 FOR J6=1 TO 6 STEP 1
1540 LET A(I,J6)=B(I,J6)=C(I,J6)=D(I,J6)=E(I,J6)=S(I,J6)=L(I,J6)=0.0
1550 NEXT J6
1560 NEXT I
1562 REM ----------------------------------------------------------
1564 REM FORMATION OF STIFFNESS MATRIX FOR EACH PILE
1566 REM ----------------------------------------------------------
1570 LET I=1
1580 LET G2=N2
1582 LET B5=K5
1584 LET B6=K5
1590 LET B2=A1*D1/(4*E1*A5)
1600 LET B2=B2↑.25
1610 LET B3=A1*D2/(4*E1*B1)
1620 LET B3=B3↑.25
1630 LET A8=2*B2*E1*A5
1640 LET A9=2*B3*E1*B1
1650 IF N1=1 THEN 1690
1660 IF N1=2 THEN 1780
1670 IF N1=3 THEN 1860
1680 IF N1=4 THEN 2010
1682 REM ----------------------------------------------------------
1684 REM STANDARD PILE MODEL
1686 REM ----------------------------------------------------------
1690 LET B(1,1)=(1+G2)*A9*B3↑2
1700 LET B(2,2)=(1+G2)*A8*B2↑2
1710 LET B(3,3)=B6*E1*A6/A3
1720 LET B(4,4)=G2*A8
1730 LET B(5,5)=G2*A9
1740 LET B(6,6)=G2*B5*A4*G3/A3
1750 LET B(1,5)=B(5,1)=G2*A9*B3
1760 LET B(2,4)=B(4,2)=-G2*A8*B2
1770 GOTO 2170
1772 REM ----------------------------------------------------------
1774 REM FIXED CANTILEVER BEAM MODEL
1776 REM ----------------------------------------------------------
1780 LET B(1,1)=(1+3*G2)*3*E1*B1/F(I)↑3
1790 LET B(2,2)=(1+3*G2)*3*E1*A5/F(I)↑3
1800 LET B(3,3)=B6*E1*A6/A3
1810 LET B(4,4)=G2*4*E1*A5/F(I)
1820 LET B(5,5)=G2*4*E1*B1/F(I)
1825 LET B(6,6)=G2*B5*A4*G3/A3
1830 LET B(1,5)=G2*6*E1*B1/F(I)↑2
1835 LET B(5,1)=B(1,5)
```

```
1840 LET B(2,4)=-G2*6*E1*A5/F(I)↑2
1845 LET B(4,2)=B(2,4)
1850 GOTO 2170
1852 REM ----------------------------------------------------------
1854 REM ELEVATED PLATFORM MODEL
1856 REM ----------------------------------------------------------
1860 LET T8=3+6*B2*F(I)+6*B2↑2*F(I)↑2+(1+G2)*2*B2↑3*F(I)↑3+G2*B3↑4*F(I)↑4
1880 LET T8=1/T8
1890 LET T9=3+6*B3*F(I)+6*B3↑2*F(I)↑2+(1+G2)*2*B3↑3*F(I)↑3+G2*B2↑4*F(I)↑4
1900 LET T9=1/T9
1910 LET B(1,1)=3*(1+G2*(1+2*B3*F(I)))*B3↑2*A9*T9
1920 LET B(2,2)=3*(1+G2*(1+2*B2*F(I)))*B2↑2*A8*T8
1930 LET B(3,3)=B6*E1*A6/A3
1940 LET B(4,4)=G2*A8*(3+6*B2*F(I)+6*B2↑2*F(I)↑2+2*B2↑3*F(I)↑3)*T8
1950 LET B(5,5)=G2*A9*(3+6*B3*F(I)+6*B3↑2*F(I)↑2+2*B3↑3*F(I)↑3)*T9
1960 LET B(6,6)=G2*B5*A4*G3/A3
1970 LET B(1,5)=3*G2*B3*A9*(1+2*B3*F(I)+B3↑2*F(I)↑2)*T8
1980 LET B(5,1)=B(1,5)
1990 LET B(2,4)=B(4,2)=-3*G2*B2*A8*(1+2*B2*F(I)+B2↑2*F(I)↑2)*T9
2000 GOTO 2170
2002 REM ----------------------------------------------------------
2004 REM LINEARLY VARYING SUBGRADE MODULUS MODEL
2006 REM ----------------------------------------------------------
2010 LET T8=(E1*A5/A1*D1)↑.2
2030 LET T9=(E1*B1/A1*D2)↑.2
2040 LET C5=A1*D1*T8
2050 LET C6=A1*D2*T9
2060 LET B(1,1)=(.411+.644*G2)*C6*T9
2070 LET B(2,2)=(.411+644*G2)*C5*T8
2080 LET B(3,3)=B6*E1*A6/A3
2090 LET B(4,4)=1.492*G2*C5*T8↑3
2100 LET B(5,5)=1.492*G2*C6*T9↑3
2110 LET B(1,5)=B(5,1)=G2*C6*T9↑2
2120 LET B(2,4)=B(4,2)=-G2*C5*T8↑2
2130 LET B(6,6)=G2*B5*A4*G3/A3
2140 REM ----------------------------------------------------------
2150 REM TEST FOR ALL VERTICAL PILES
2160 REM ----------------------------------------------------------
2170 IF K3-1<>0 THEN 2270
2200 FOR Z9=1 TO 6 STEP 1
2210 LET A(Z9,Z9)=1
2220 NEXT Z9
2230 GOTO 2730
2240 REM ----------------------------------------------------------
2250 REM PREPARATION FOR CONSTRUCTION OF TRANSFORMATION MATRIX
2260 REM ----------------------------------------------------------
2270 IF N(I)<>0 THEN 2330
2300 LET S2=0
2310 LET C3=1
2320 GOTO 2370
2330 LET P1=1+N(I)*N(I)
2340 LET P1=SQR(P1)
2350 LET S2=N(I)/P1
2360 LET C3=1/P1
2370 LET T1=N(I)
2380 LET G1=ATN(T1)
2390 IF P(I)<>0 THEN 2450
2420 LET S3=0
2430 LET C4=1
2440 GOTO 2500
2450 LET P(I)=P(I)/57.2957795131
```

```
2460 LET T1=P(I)
2470 LET S3=SIN(T1)
2480 LET C4=COS(T1)
2490 LET P(I)=P(I)*57.2957795131
2500 REM ----------------------------------------------------
2510 REM PILE TRANSFORMATION MATRIX
2520 REM ----------------------------------------------------
2530 LET A(1,1)=C3*C4
2540 LET A(1,2)=-S3
2550 LET A(1,3)=S2*C4
2560 LET A(2,1)=C3*S3
2570 LET A(2,2)=C4
2580 LET A(2,3)=S2*S3
2590 LET A(3,1)=-S2
2600 LET A(3,3)=C3
2610 LET A(4,4)=A(1,1)
2620 LET A(4,5)=A(1,2)
2630 LET A(4,6)=A(1,3)
2640 LET A(5,4)=A(2,1)
2650 LET A(5,5)=A(2,2)
2660 LET A(5,6)=A(2,3)
2670 LET A(6,4)=A(3,1)
2680 LET A(6,5)=A(3,2)
2690 LET A(6,6)=A(3,3)
2700 REM ----------------------------------------------------
2710 REM PILE STATICS MATRIX
2720 REM ----------------------------------------------------
2730 LET C(1,1)=1
2740 LET C(2,2)=1
2750 LET C(3,3)=1
2760 LET C(4,4)=G2
2770 LET C(5,5)=G2
2780 LET C(6,6)=G2
2790 LET C(4,2)=-Z
2800 LET C(4,3)=Y(I)
2810 LET C(5,1)=Z
2820 LET C(5,3)=-X(I)
2830 LET C(6,1)=-Y(I)
2840 LET C(6,2)=X(I)
2850 REM ----------------------------------------------------
2860 REM MATRIX MULTIPLICATIONS AND MANIPULATIONS
2870 REM ----------------------------------------------------
2880 FOR Z9=1 TO 6 STEP 1
2890 FOR J6=1 TO 6 STEP 1
2900 LET D(Z9,J6)=A(J6,Z9)
2910 LET E(Z9,J6)=C(J6,Z9)
2920 NEXT J6
2930 NEXT Z9
2940 MAT R=C*A
2950 MAT T=R
2960 MAT R=T*B
2970 MAT T=R
2980 MAT R=T*D
2990 MAT T=R
3000 MAT R=T*E
3010 REM ----------------------------------------------------
3020 REM INDIVIDUAL PILE OUTPUT
3030 REM ----------------------------------------------------
3040 IF M1<>0 THEN 4260
3070 IF J1-2<>0 THEN 3460
3100 IF I-1<>0 THEN 3150
```

```
3130 PRINT "      "
3140 PRINT " ************************** INDIVIDUAL PILE OUTPUT ************";
3141 PRINT "************"
3150 GOTO 3170
3160 PRINT "      "
3170 PRINT
3171 PRINT
3175 PRINT "    PILE NUMBER .... ";I
3180 PRINT
3181 PRINT
3190 PRINT " ------------------------------ TRANS MATRIX ----------------";
3191 PRINT "--------------"
3193 PRINT
3210 MAT PRINT USING 3415,A
3220 PRINT
3221 PRINT
3230 PRINT " ----------------------- ELASTIC PILE CONSTANT MATRIX B ----------";
3231 PRINT "--------"
3232 PRINT
3250 MAT PRINT USING 3415,B
3260 PRINT
3261 PRINT
3270 PRINT " ------------------------------ STATICS MATRIX -------------------";
3271 PRINT "--------"
3272 PRINT
3290 MAT PRINT USING 3415,C
3300 PRINT
3301 PRINT
3310 PRINT " ----------------- TRANSPOSE OF A TRANSFORMATION MATRIX --------";
3311 PRINT "---------"
3312 PRINT
3330 MAT PRINT USING 3415,D
3340 PRINT
3341 PRINT
3350 PRINT " ----------------------- TRANSPOSE STATICS MATRIX ----------------";
3351 PRINT "--------"
3352 PRINT
3370 MAT PRINT USING 3415,E
3380 PRINT
3381 PRINT
3390 PRINT " ------------------------- RESULTS OF C A B D E ----------------";
3391 PRINT "---------"
3392 PRINT
3410 MAT PRINT USING 3415,R
3412 PRINT
3415 :##.#####↑↑↑↑ ##.#####↑↑↑↑ ##.#####↑↑↑↑ ##.#####↑↑↑↑ ##.####↑↑↑↑ ##.####↑↑↑↑
3420 PRINT
3430 REM -----------------------------------------------------------------
3440 REM FORMATION OF TOTAL STIFFNESS MATRIX
3450 REM -----------------------------------------------------------------
3460 MAT S=S+R
3465 MAT L=L+R
3470 IF I-K<0 THEN 3490
3480 IF I-K>=0 THEN 3540                          000082
3490 LET I=I+1
3500 GOTO 1590
3510 REM -----------------------------------------------------------------
3520 REM DEFLECTIONS OF FOUNDATION AND SAMPLE POINTS
3530 REM -----------------------------------------------------------------
3540 LET S6=.00001
3550 FOR Z9=1 TO 6 STEP 1
```

```
3560 FOR J6=1 TO 6 STEP 1
3570 LET S4=ABS(S(Z9,J6))
3590 IF S4-S6>0 THEN 3610
3600 LET S(Z9,J6)=0
3601 LET L(Z9,J6)=0
3610 NEXT J6
3620 NEXT Z9
4000 FOR Z9=1 TO 6 STEP 1
4005 IF S(Z9,Z9)>0 THEN 4030
4010 LET S(Z9,Z9)=11.0
4015 PRINT USING 4020,Z9,Z9
4020 :    S(##,##)=0 CHANGED TO 11.0
4025 LET L(Z9,Z9)=11.0
4030 NEXT Z9
4031 LET K4=I1
4032 REM -------------------------------------------------
4033 REM CALL SUBROUTINE PINT
4034 LET U1=1
4035 FOR I9=1 TO 6 STEP 1
4036 FOR J9=1 TO 6 STEP 1
4037 LET O((I9-1)*6+J9)=L(I9,J9)
4038 NEXT J9
4039 NEXT I9
4040 GOSUB 4800
4041 REM -------------------------------------------------
4048 FOR I9=1 TO 6 STEP 1
4049 FOR J9=1 TO 6 STEP 1
4050 LET L(I9,J9)=O((I9-1)*6+J9)
4051 NEXT J9
4052 NEXT I9
4053 IF K4-I1<0 THEN 590
4054 IF L1<=0 THEN 4075
4055 PRINT "L1=";L1
4056 PRINT "N.B. WITH NO SUBGRADE, THIS PILE CONFIGURATION IS SEMI-"
4060 PRINT "STABEL AND CANNOT BE ANLYZED. THEREFORE,A SUBGRADE"
4065 PRINT USING 4070,A2
4070 :MODULUS OF ####.#### PCI HAS BEEN INSERTED"
4075 MAT W=Q
4080 MAT V=L*W
4085 MAT Q=W
4090 IF N3<=0 THEN 4120
4095 FOR I9=1 TO N3 STEP 1
4100 LET H(I9,1)=V(1,1)+M(I9,3)*V(5,1)+M(I9,2)*V(6,1)
4105 LET H(I9,2)=-V(2,1)+M(1,3)*V(4,1)-M(I9,1)*V(6,1)
4110 LET H(I9,3)=V(3,1)-M(I9,2)*V(4,1)-M(I9,1)*V(5,1)
4115 NEXT I9
4120 IF J1-2<>0 THEN 4235
4125 REM -------------------------------------------------
4130 REM TOTAL PILE GROUP OUTPUT
4135 REM -------------------------------------------------
4140 IF I3-1<>0 THEN 4235
4145 GOSUB 4595
4150 PRINT " ******************** TOTAL PILE GROUP OUTPUT ****************";
4155 PRINT "********"
4160 GOSUB 4615                                                  000083
4161 PRINT
4165 PRINT " ----------------------- STIFFNESS MATRIX -------------------";
4166 PRINT "-----"
4170 :##.####↑↑↑↑ ##.####↑↑↑↑ ##.####↑↑↑↑ ##.####↑↑↑↑ ##.####↑↑↑↑ ##.####↑↑↑↑
4175 PRINT
4180 MAT PRINT USING 4170,S
```

```
4185 GOSUB 4615
4190 PRINT " ------------------- INVERSE OF STIFFNESS MATRIX ---------------";
4191 PRINT "-----"
4195 PRINT "                              (FLEXIBILITY MATRIX)"
4200 PRINT
4205 MAT PRINT USING 4170,L
4210 GOSUB 4800
4215 REM GOSUB 4615
4220 REM PRINT "          (STIFFNESS MATRIX)X((FLEXIBILITY MATRIX)"
4225 REM PRINT
4230 REM MAT PRINT USING 4170,T
4235 LET M1=2
4240 GOTO 1570
4245 REM ---------------------------------------------------------------
4250 REM PILE DISPLACEMENTS AND LOADS
4255 REM ---------------------------------------------------------------
4260 MAT T=D*E
4265 MAT U=T*V
4270 IF J1-2<>0 THEN 4295
4275 GOSUB 4615
4280 PRINT " ----------------------- RESULTS OF (D) (E) -------------------";
4281 PRINT "-------"
4285 PRINT
4290 MAT PRINT USING 4170,T
4295 SETW :2 TO 2*(I5-1)*6+1
4300 WRITE :2,U(1,1),U(2,1),U(3,1),U(4,1),U(5,1),U(6,1)
4302 LET I5=I5+1
4305 MAT G=B*U
4310 SETW :3 TO 2*(I6-1)*6+1
4315 WRITE :3,G(1,1),G(2,1),G(3,1),G(4,1),G(5,1),G(6,1)
4317 LET I6=I6+1
4320 IF I-K>=0 THEN 4350
4325 LET I=I+1
4330 GOTO 1590
4335 REM ---------------------------------------------------------------
4340 REM FINAL OUTPUT
4345 REM ---------------------------------------------------------------
4350 IF J1-2<>0 THEN 4665
4355 IF I3-1<>0 THEN 4365
4357 GOSUB 4595
4358 GOSUB 4595
4360 PRINT "*************************** FINAL OUTPUT ***************************";
4361 PRINT "********"
4362 PRINT
4363 PRINT
4364 PRINT
4365 PRINT TAB(2);"LOAD";TAB(13);"X";TAB(25);"Y";TAB(37);"Z";TAB(49);"XX";
4367 PRINT TAB(61);"YY";TAB(71);"ZZ"
4370 PRINT TAB(2);"NO.";TAB(12);"LOAD";TAB(24);"LOAD";TAB(36);"LOAD";TAB(47);
4372 PRINT "MOMENT";TAB(59);"MOMENT";TAB(69);"MOMENT"
4375 PRINT USING 4380,I3,Q(1,1),Q(2,1),Q(3,1),Q(4,1),Q(5,1),Q(6,1)
4377 PRINT
4380 :### ########.## ########.## ########.## ########.## ########.## #####.###
4385 GOSUB 4595
4390 PRINT "                         FOUNDATION DEFLECTIONS"            000084
4395 PRINT
4400 PRINT TAB(6);"X";TAB(19);"Y";TAB(30);"Z";TAB(42);"XX";TAB(54);"YY";
4402 PRINT TAB(66);"ZZ"
4405 PRINT TAB(3);"MOVEMENT";TAB(15);"MOVEMENT";TAB(27);"MOVEMENT";TAB(39);
4407 PRINT "ROTATION";TAB(51);"ROTATION";TAB(63);"ROTATION"
4410 PRINT
```

```
4415 PRINT USING 4170,U(1,1),U(2,1),U(3,1),U(4,1),U(5,1),U(6,1)
4420 IF N3=0 THEN 4470
4425 GOSUB 4595
4430 PRINT TAB(24);"SAMPLE-POINT DEFLECTIONS"
4432 PRINT
4435 PRINT TAB(1);"POINT";TAB(12);"X";TAB(25);"Y";TAB(36);"Z";TAB(46);"X";
4440 PRINT TAB(58);"Y";TAB(68);"Z"
4441 PRINT TAB(2);"NO.";TAB(11);"OLD";TAB(24);"OLD";TAB(35);"OLD";TAB(45);
4442 PRINT "NEW";TAB(57);"NEW";TAB(67);"NEW"
4445 PRINT
4450 FOR I9=1 TO N3 STEP 1
4455 PRINT USING 4460,I9,H(I9,1),H(I9,2),H(I9,3),H(I9,1),H(I9,2),H(I9,3)
4460 :###   ##.####↑↑↑↑  ##.####↑↑↑↑ ##.###↑↑↑↑ ##.###↑↑↑↑ ##.###↑↑↑↑ ##.####↑↑↑↑
4462 NEXT I9
4465 GOSUB 4615
4470 GOSUB 4595
4472 PRINT "                              LOCAL PILE DISPLACEMENT"
4474 PRINT
4479 PRINT
4480 PRINT TAB(11);"X";TAB(24);"Y";TAB(36);"Z";TAB(46);"XX";TAB(57);"YY";
4482 PRINT TAB(68);"ZZ"
4485 PRINT TAB(2);"NO.";TAB(8);"MOVEMENT";TAB(21);"MOVEMENT";TAB(33);"MOVEMENT";
4487 PRINT TAB(43);"ROTATION";TAB(54);"ROTATION";TAB(65);"ROTATION"
4490 PRINT
4495 SETW :2 TO 1
4500 FOR I9=1 TO K STEP 1
4505 READ :2,U(1,1),U(2,1),U(3,1),U(4,1),U(5,1),U(6,1)
4510 PRINT USING 4460,I9,U(1,1),U(2,1),U(3,1),U(4,1),U(5,1),U(6,1)
4515 NEXT I9
4520 GOSUB 4595
4525 PRINT "                              LOCAL PILE LOADS"
4530 PRINT
4535 PRINT TAB(11);"X";TAB(25);"Y";TAB(36);"Z";TAB(47);"XX";TAB(57);"YY";
4537 PRINT TAB(69);"ZZ"
4540 PRINT TAB(2);"NO.";TAB(9);"FORCE";TAB(23);"FORCE";TAB(34);"FORCE";
4542 PRINT TAB(45);"MOMENT";TAB(55);"MOMENT";TAB(67);"MOMENT"
4545 PRINT
4550 SETW :3 TO 1
4555 FOR I9=1 TO K STEP 1
4560 READ :3,G(1,1),G(2,1),G(3,1),G(4,1),G(5,1),G(6,1)
4565 PRINT USING 4460,I9,G(1,1),G(2,1),G(3,1),G(4,1),G(5,1),G(6,1)
4567 NEXT I9
4570 GOSUB 4615
4575 PRINT " XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX";
4576 PRINT "XXXXXXXXX"
4577 GOTO 4665
4580 REM -------------------------------------------------------------------
4585 REM PRINT SUBROUTINES
4590 REM -------------------------------------------------------------------
4595 FOR I9=1 TO 6 STEP 1
4600 PRINT
4605 NEXT I9
4610 RETURN
4615 FOR I9=1 TO 2 STEP 1
4620 PRINT                                              000085
4625 NEXT I9
4630 RETURN
4635 REM -------------------------------------------------------------------
4640 REM FILE OUTPUT
4645 REM -------------------------------------------------------------------
4665 SETW :1 TO 1
```

```
4670 MAT WRITE :1,M,Q,V,H,U,G,L,S
4675 WRITE :1,I4,I3,N1,N2,K5,K3,N3,E1,G3,A1
4680 WRITE :1,A3,A6,D1,D2,A5,B1,A4,K,Z,U1,K8,Z4,Z2,Z3
4681 FOR I9=1 TO K8 STEP 1
4682 WRITE :1,F(I9)
4683 NEXT I9
4685 FOR I9=1 TO K8 STEP 1
4690 WRITE :1,X(I9),Y(I9),N(I9),P(I9)
4695 NEXT I9
4725 CHAIN "*PIL"
4800 REM -------------------------------------------------------
4805 REM SUBROUTINE 6X6 MATRIX INVERSION
4810 REM -------------------------------------------------------
4815 LET Y1=6
4820 LET D4=1
4825 LET N4=-Y1
4830 FOR K9=1 TO Y1 STEP 1
4835 LET N4=N4+Y1
4840 LET J(K9)=K9
4845 LET I(K9)=K9
4850 LET L8=N4+K9
4855 LET B5=O(L8)
4860 FOR J9=K9 TO Y1 STEP 1
4865 LET Z1=Y1*(J9-1)
4870 FOR I9=K9 TO Y1 STEP 1
4875 LET J2=Z1+I9
4880 IF ABS(B5)>=ABS(O(J2)) THEN 4900
4885 LET B5=O(J2)
4890 LET J(K9)=I9
4895 LET I(K9)=J9
4900 NEXT I9
4905 NEXT J9
4910 LET J9=J(K9)
4915 IF J9<=K9 THEN 4960
4920 LET K7=K9-Y1
4925 FOR I9=1 TO Y1 STEP 1
4930 LET K7=K7+Y1
4935 LET H1=-O(K7)
4940 LET J3=K7-K9+J9
4945 LET O(K7)=O(J3)
4950 LET O(J3)=H1
4955 NEXT I9
4960 LET I9=I(K9)
4965 IF I9<=K9 THEN 5010
4970 LET P2=Y1*(I9-1)
4975 FOR J9=1 TO Y1 STEP 1
4980 LET J4=N4+J9
4985 LET J3=P2+J9
4990 LET H1=-O(J4)
4995 LET O(J4)=O(J3)
5000 LET O(J3)=H1
5005 NEXT J9
5010 IF B5<>0 THEN 5025
5015 LET D4=0
5020 GOTO 5275
5025 FOR I9=1 TO Y1 STEP 1
5030 IF I9-K9=0 THEN 5045
5035 LET K6=N4+I9
5040 LET O(K6)=O(K6)/(-B5)
5045 NEXT I9
5050 FOR I9=1 TO Y1 STEP 1
```

```
5055 LET K6=N4+I9
5060 LET J2=I9-Y1
5065 FOR J9=1 TO Y1 STEP 1
5070 LET J2=J2+Y1
5075 IF I9-K9=0 THEN 5095
5080 IF J9-K9=0 THEN 5095
5085 LET P3=J2-I9+K9
5090 LET O(J2)=O(K6)*O(P3)+O(J2)
5095 NEXT J9
5100 NEXT I9
5105 LET P3=K9-Y1
5110 FOR J9=1 TO Y1 STEP 1
5115 LET P3=P3+Y1
5120 IF J9-K9=0 THEN 5130
5125 LET O(P3)=O(P3)/B5
5130 NEXT J9
5135 LET D4=D4*B5
5140 LET O(L8)=1/B5
5145 NEXT K9
5150 LET K9=Y1
5155 LET K9=K9-1
5160 IF K9<=0 THEN 5275
5165 LET I9=J(K9)
5170 IF I9<=K9 THEN 5220
5175 LET Q1=Y1*(K9-1)
5180 LET Q2=Y1*(I9-1)
5185 FOR J9=1 TO Y1 STEP 1
5190 LET J4=Q1+J9
5195 LET H1=O(J4)
5200 LET J2=Q2+J9
5205 LET O(J4)=-O(J2)
5210 LET O(J2)=H1
5215 NEXT J9
5220 LET J9=J(K9)
5225 IF J9<=K9 THEN 5155
5230 LET K7=K9-Y1
5235 FOR I9=1 TO Y1 STEP 1
5240 LET K7=K7+Y1
5245 LET H1=O(K7)
5250 LET J2=K7-K9+J9
5255 LET O(K7)=-O(J2)
5260 LET O(J2)=H1
5265 NEXT I9
5270 GOTO 5155
5275 RETURN
9999 END

END OF LISTING



FILE    *PIL


0005 REM ****************************************************************
0010 REM SUBROUTINE PILES1
0015 REM ****************************************************************
0017 DISP "          PILE ANALYSIS"
0020 REM
0025 REM
0030 REM --------------------------------------------------------------
```

```
0035 REM FILE INPUT
0040 REM ---------------------------------------- --------------------
0042 DCL SINGLE
0045 FILES COMM1,COMM2;COMM5;COMM6;COMM7;COM1;COM8;CO1;ZP1;AD;BB
0050 SETW :1 TO 1
0055 SETW :2 TO 1
0060 SETW :3 TO 1
0062 SETW :4 TO 1
0064 SETW :5 TO 1
0065 READ :1,A1,G3,E1,N4,N3,U2,J6
0070 ON N4 GOTO 72,76,86
0072 READ :1,K,S6,Z1,Z2,Z3,Z4,Z5,Z6,Z7,Z8,Z9,Y1,Y2,K8
0074 GOTO 127
0076 READ :1,H2,A3,D1,D2,A5,B1,A4,A6,B4,B5,C7
0078 FOR I9=1 TO 2 STEP 1
0080 READ :1,F(I9)
0082 NEXT I9
0084 GOTO 127
0086 READ :1,K,N3,N1,N2,K5,K3,K8
0088 FOR I9=1 TO K STEP 1
0090 READ :1,N(I9),P(I9),X(I9),Y(I9),Z,F(I9),A3
0092 NEXT I9
0094 READ :1,A4,A5,B1,A6,D1,D2,B4,B5,C7
0095 READ :1,Q(1,1),Q(2,1),Q(3,1),Q(4,1),Q(5,1),Q(6,1)
0096 FOR I9=1 TO 10 STEP 1
0098 FOR J9=1 TO 3 STEP 1
0100 LET M(I9,J9)=0.0
0102 NEXT J9
0104 NEXT I9
0106 IF N3=0 THEN 127
0108 FOR I9=1 TO N3 STEP 1
0110 READ :1,M(I9,1),M(I9,2),M(I9,3)
0112 NEXT I9
0127 IF U2=0 THEN 275
0130 MAT READ :2,M(10,3),Q(6,1),V(6,1),H(10,3),U(6,1),G(6,1),L(6,6),S(6,6)
0135 READ :2,J6,I3,N1,N2,K5,K3,N3,E1,G3,A1
0140 READ :2,A3,A6,D1,D2,A5,B1,A4,K,Z,U1,K8,B5,B4,C7
0141 FOR I9=1 TO K8 STEP 1
0142 READ :2,F(I9)
0143 NEXT I9
0145 FOR I9=1 TO K8 STEP 1
0150 READ :2,X(I9),Y(I9),N(I9),P(I9)
0155 NEXT I9
0170 MAT READ :4,C(10,60)
0173 FOR I9=1 TO 10 STEP 1
0176 READ :4,B(I9)
0179 NEXT I9
0180 READ :4,N5,K6,I4
0182 IF N4<>2 THEN 191
0185 IF N5<>1 THEN 191
0188 READ :4,P1,T1,H1,J1,X1,X2,X3,X4,X5,X6,X7,X8,X9,W1,W2
0191 GOTO 235
0235 REM ----------------------------------------------------------------
0240 REM DIMENSIONING OF MATRIX VARIABLES
0245 REM ----------------------------------------------------------------
0250 DIM B(10),N(50),P(50),X(50),Y(50),Q(6,1),V(6,1),U(6,1),G(6,1),O(6)
0255 DIM L(6,6),S(6,6),C(10,60),A(50,3),M(10,3),H(10,3)
0260 REM ----------------------------------------------------------------
0265 REM MARKER REDIRECTING PROGRAM FLOW AFTER CHAINNING S3363
0270 REM ----------------------------------------------------------------
0275 IF U2=1 THEN 1720
```

```
0280 REM ------------------------------------------------------------
0285 REM MAINLINE OF SUBROUTINE PILES
0290 REM ------------------------------------------------------------
0295 LET I3=1
0300 LET P1=0.0
0305 LET T1=0.0
0310 FOR I9=1 TO 10 STEP 1
0315 FOR J9=1 TO 3 STEP 1
0320 LET H(I9,J9)=0.0
0325 NEXT J9
0330 NEXT I9
0335 FOR I9=1 TO 6 STEP 1
0340 FOR J9=1 TO 6 STEP 1
0345 LET L(I9,J9)=0.0
0350 LET S(I9,J9)=0.0
0355 NEXT J9
0360 NEXT I9
0365 FOR I9=1 TO 6 STEP 1
0370 LET U(I9,1)=0.0
0375 LET U(I9,1)=0.0
0380 LET G(I9,1)=0.0
0385 LET O(I9)=0.0
0390 NEXT I9
0395 FOR I9=1 TO 50 STEP 1
0400 FOR J9=1 TO 3 STEP 1
0405 LET A(I9,J9)=0.0
0410 NEXT J9
0415 NEXT I9
0420 FOR I9=1 TO 10 STEP 1
0425 LET B(I9)=0.0
0430 NEXT I9
0435 FOR I9=1 TO 10 STEP 1
0440 FOR J9=1 TO 60 STEP 1
0445 LET C(I9,J9)=0.0
0450 NEXT J9
0455 NEXT I9
0465 ON N4 GOTO 470,655,780
0470 LET M1=2
0475 LET M2=1
0480 LET K5=1
0485 LET K3=1
0490 LET N3=0
0495 FOR I9=1 TO 10 STEP 1
0500 FOR J9=1 TO 3 STEP 1
0505 LET M(I9,J9)=0.0
0510 NEXT J9
0515 NEXT I9
0520 FOR I9=1 TO K STEP 1
0525 LET N(I9)=0.0
0530 LET P(I9)=0.0
0535 LET Y(I9)=0.0
0540 LET Z=0.0
0545 NEXT I9
0550 LET S5=S6
0555 LET S6=S6/12.0
0560 FOR I9=1 TO K STEP 1
0565 LET X(I9)=S6*(I9-1)
0570 LET A3=Z1
0575 LET A4=Z2
0580 LET A5=Z3
0585 LET B1=Z4
```

```
0590 LET A6=Z5
0595 LET D1=Z6
0600 LET D2=Z7
0605 LET F(I9)=Z8
0610 LET B4=Z9
0615 LET B5=Y1
0620 LET C7=Y2
0625 NEXT I9
0630 LET Q(1,1)=1.0
0635 FOR I9=2 TO 6 STEP 1
0640 LET Q(I9,1)=0.0
0645 NEXT I9
0650 GOTO 785
0655 GOTO 660
0660 LET N1=2
0665 LET N2=1
0670 LET K5=1
0675 LET K=2
0677 LET K8=K
0680 LET K3=0.0
0685 LET N3=0.0
0690 FOR I9=1 TO 10 STEP 1
0695 FOR J9=1 TO 3 STEP 1
0700 LET M(I9,J9)=0.0
0705 NEXT J9
0710 NEXT I9
0715 FOR I9=1 TO 2 STEP 1
0720 LET P(I9)=0.0
0725 LET X(I9)=0.0
0730 LET Y(I9)=0.0
0735 LET Z=0.0
0740 NEXT I9
0745 LET N(1)=0.0
0750 LET N(2)=H2
0755 LET Q(1,1)=1.0
0760 FOR I9=2 TO 6 STEP 1
0765 LET Q(I9,1)=0.0
0770 NEXT I9
0775 GOTO 785
0780 GOTO 785
0785 ON N4 GOTO 787,967,1083
0787 GOSUB 2055
0788 GOSUB 2035
0790 PRINT "              PILE DATA"
0795 PRINT "              ---- ----"
0797 GOSUB 2035
0800 PRINT USING 805,A1
0805 :SUBGRADE MODULUS        ********.****   K/FT**3
0810 PRINT USING 825,G3
0815 :TORSIONAL MODULUS       ********.****   K/IN**2
0820 PRINT USING 825,E1
0825 :MODULUS OF ELASTICITY ********.****   K/IN**2
0830 PRINT "NUMBER OF PILES",K
0835 PRINT USING 840,S5
0840 :SPACING BETWEEN PILES  ********.**** IN
0845 GOSUB 2035
0850 PRINT USING 855,Z2
0855 :POLAR MOMENT OF INERTIA             ********.****   IN**4
0860 PRINT USING 865,Z3
0865 :MOMENT OF INERTIA AT X-X AXIS       ********.****   IN**4
0870 PRINT USING 875,Z4
```

000090

```
0875 :MOMENT OF INERTIA AT Y-Y AXIS          ########.####   IN**4
0880 PRINT USING 885,Z5
0885 :CROSS-SECTIONAL AREA                    ########.####   IN**2
0890 PRINT USING 895,Z6
0895 :PROJECTED WIDTH IN X-X DIRECTION        ########.####   IN
0900 PRINT USING 905,Z7
0905 :PROJECTED WIDTH IN Y-Y DIRECTION        ########.####   IN
0910 PRINT USING 915,Z8
0915 :CANTILEVER LENGTH                       #########.####  FT
0920 PRINT USING 925,Z1
0925 :LENGTH                                  ########.####   FT
0930 PRINT USING 935,Z9
0935 :YIELD STRESS                            ########.####   K/IN**2
0940 PRINT USING 945,Y1
0945 :NEUTRAL AXIS-OUTER FIBERS LENGTH        ########.####   IN
0950 PRINT USING 955,Y2
0955 :VERTICAL LOAD                           ########.####   K
0960 GOSUB 2035
0965 GOTO 1395
0967 GOSUB 2055
0970 PRINT "                    PILE DATA"
0975 PRINT "                    ---- ----"
0980 GOSUB 2035
0985 PRINT USING 805,A1
0990 PRINT USING 815,G3
0995 PRINT USING 825,E1
1000 PRINT "NUMBER OF PILES";K
1005 GOSUB 2035
1007 PRINT "                          PILE1           PILE2"
1010 PRINT USING 1015,N(1),N(2)
1012 PRINT USING 1016,F(1),F(2)
1015 :VERTICAL SLOPE           ########.####     ########.####
1016 :CANTILEVER LENGTH        ########.####     #########.####
1017 GOSUB 2035
1020 PRINT USING 855,A4
1025 PRINT USING 865,A5
1030 PRINT USING 875,B1
1035 PRINT USING 885,A6
1040 PRINT USING 895,D1
1045 PRINT USING 905,D2
1055 PRINT USING 925,A3
1060 PRINT USING 935,B4
1065 PRINT USING 945,B5
1070 PRINT USING 955,C7
1075 GOSUB 2035
1080 GOTO 1395
1083 GOSUB 2035
1084 GOSUB 2055
1085 PRINT "                    PILE DATA"
1090 PRINT "                    ---- ----"
1092 GOSUB 2035
1095 PRINT USING 805,A1
1100 PRINT USING 815,G3
1105 PRINT USING 825,E1
1110 PRINT "NUMBER OF PILES";K
1115 GOSUB 2035
1120 PRINT "NUMBER OF SAMPLE POINTS";N3
1125 PRINT "TECHNIQUE LOGIC";N1
1130 PRINT "PILE FIXITY LOGIC";N2
1135 PRINT "SHAPE FACTOR";K5
1140 PRINT "VERTICAL PILE LOGIC";K3
```

000091

```
1145 GOSUB 2055
1147 GOSUB 2035
1150 PRINT TAB(1);"PILE";TAB(8);"VER.";TAB(16);"HOR.";TAB(54);"CANT."
1152 PRINT TAB(1);"NO.";TAB(7);"SLOPE";TAB(15);"ANGLE";TAB(23);"X-COOR.";
1154 PRINT TAB(33);"Y-COOR.";TAB(43);"Z-COOR.";TAB(53);"LENGTH";TAB(62);"LENGHT"
1156 PRINT TAB(15);"(DEG)";TAB(24);"(IN)";TAB(34);"(IN)";TAB(44);"(IN)";
1158 PRINT TAB(54);"(FT)";TAB(63);"(FT)"
1165 FOR I9=1 TO K STEP 1
1170 PRINT USING 1175,I9,N(I9),P(I9),X(I9),Y(I9),Z,F(I9),A3
1175 :###   ##.####  ####.##  ####.###   ####.###   ####.###   ####.##   ####.##
1180 NEXT I9
1182 GOSUB 2055
1183 GOSUB 2035
1185 PRINT TAB(22);"MOM. OF";TAB(33);"MOM. OF";TAB(54);"PROJ.";TAB(63);"PROJ."
1187 PRINT TAB(1);"PILE";TAB(9);"POLAR MOM.";TAB(22);"INER. AT";TAB(33);
1189 PRINT "INER. AT";TAB(43);"X-SECT.";TAB(53);"WIDTH IN";TAB(63);"WIDTH IN"
1191 PRINT TAB(1);"NO.";TAB(9);"OF INERTIA";TAB(22);"X-X AXIS";TAB(33);
1193 PRINT "Y-Y AXIS";TAB(44);"AREA";TAB(53);"X-X DIR.";TAB(63);"Y-Y DIR."
1195 PRINT TAB(10);"(IN**4)";TAB(22);"(IN**4)";TAB(33);"(IN**4)";TAB(43);
1197 PRINT "(IN**2)";TAB(54);"(IN)";TAB(64);"(IN)"
1205 FOR I9=1 TO K STEP 1
1210 PRINT USING 1215,I9,A4,A5,B1,A6,D1,D2
1215 :###     ######.##     ######.##   ######.##   ####.##     ###.##     ###.##
1220 NEXT I9
1225 PRINT
1227 GOSUB 2055
1230 PRINT TAB(37);"NEUTRAL AXIS"
1232 PRINT TAB(1);"PILE";TAB(20);"YIELD";TAB(37);"OUTER FIBERS";TAB(61);
1234 PRINT "VERTICAL"
1236 PRINT TAB(1);"NO.";TAB(19);"STRESS";TAB(40);"LENGTH";TAB(63);"LOAD"
1238 PRINT TAB(17);"(K/IN**2)";TAB(41);"(IN)";TAB(64);"(K)"
1250 FOR I9=1 TO K STEP 1
1255 PRINT USING 1260,I9,B4,B5,C7
1260 :###               ###.####              ###.####             ###.####
1265 NEXT I9
1270 GOSUB 2055
1275 PRINT TAB(33);"FORCES"
1276 PRINT
1278 PRINT TAB(7);"X-DIRECTION";TAB(31);"Y-DIRECTION";TAB(56);"Z-DIRECTION"
1281 PRINT TAB(11);"(K)";TAB(34);"(K)";TAB(60);"(K)"
1292 PRINT USING 1295,Q(1,1),Q(2,1),Q(3,1)
1295 :         #####.###              #####.###             #####.###
1300 GOSUB 2055
1305 PRINT TAB(32);"MOMENTS"
1306 PRINT
1310 PRINT TAB(11);"X-X AXIS";TAB(33);"Y-Y AXIS";TAB(56);"Z-Z AXIS"
1315 PRINT TAB(12);"(FT*K)";TAB(34);"(FT*K)";TAB(57);"(FT*K)"
1322 PRINT USING 1295,Q(4,1),Q(5,1),Q(6,1)
1325 IF N3=0 THEN 1395
1330 GOSUB 2055
1335 PRINT TAB(30);"SAMPLE POINTS"
1337 PRINT TAB(5);"POINT"
1341 PRINT TAB(4);"NUMBER";TAB(19);"X-COORDINATE";TAB(39);"Y-COORDINATE";
1343 PRINT TAB(59);"Z-COORDINATE"
1345 PRINT TAB(23);"(IN)";TAB(43);"(IN)";TAB(63);"(IN)"
1347 FOR I9=1 TO N3 STEP 1
1349 PRINT USING 1353,I9,M(I9,1),M(I9,2),M(I9,3)
1351 NEXT I9
1353 :    ###           ####.####          ####.####           ####.####
1370 FOR I9=1 TO K STEP 1
1375 LET X(I9)=X(I9)/12.0
```

```
1380 LET Y(I9)=Y(I9)/12.0
1382 NEXT I9
1385 LET Z=Z/12.0
1395 LET K6=K
1400 REM FOR I9=1 TO K STEP 1
1405 LET A4=A4/20736.0
1410 LET A5=A5/20736.0
1415 LET B1=B1/20736.0
1420 LET A6=A6/144.0
1425 LET D1=D1/12.0
1427 LET D2=D2/12.0
1430 LET B4=B4*144.0
1435 LET B5=B5/12.0
1440 REM NEXT I9
1445 LET G3=G3*144.0
1450 LET E1=E1*144.0
1455 IF N3=0 THEN 1485
1460 FOR I9=1 TO N3 STEP 1
1465 FOR J9=1 TO 3 STEP 1
1470 LET M(I9,J9)=M(I9,J9)/12.0
1475 NEXT J9
1480 NEXT I9
1485 GOTO 1490
1490 REM ------------------------------------------------
1495 REM BEGINNING OF LOOP TO PREFORM THREE DIMENSIONAL PILE ANALYSIS
1500 REM ------------------------------------------------
1505 LET N5=0
1510 LET N5=N5+1
1515 IF N4<>2 THEN 1525
1520 IF N5<>1 THEN 1525
1522 GOTO 1530
1525 GOTO 1660
1530 LET H1=N(1)
1535 LET J1=P(1)
1540 LET X1=X(1)
1545 LET X2=Y(1)
1550 LET X3=Z
1555 LET X4=A5
1560 LET X5=B1
1565 LET X6=A4
1570 LET X7=A6
1575 LET X8=D1
1580 LET X9=D1
1585 LET W1=F(1)
1590 LET W2=A3
1595 LET N(1)=N(2)
1600 LET P(1)=P(2)
1605 LET X(1)=X(2)
1610 LET Y(1)=Y(2)
1615 LET Z=Z
1620 LET A5=A5
1625 LET B1=B1
1630 LET A4=A4
1635 LET A6=A6
1640 LET D1=D1
1645 LET D2=D2
1650 LET F(1)=F(2)
1655 LET A3=A3
1660 LET K=N5
1665 IF A4-1<>0 THEN 1690
1670 GOTO 1675
```

```
1675 FOR I8=1 TO K STEP 1
1680 LET X(I8)=S6*(I8-1)
1685 NEXT I8
1690 LET I4=K6-N5+1
1695 REM *******************************************************************
1700 REM *           CALL SUBROUTINE S3363
1705 REM *******************************************************************
1710 LET U2=1
1715 GOTO 2085
1720 LET U2=0
1722 SETW :3 TO 1
1725 FOR I8=1 TO K STEP 1
1729 READ :3,U(1,1),U(2,1),U(3,1),U(4,1),U(5,1),U(6,1)
1731 FOR J9=1 TO 3 STEP 1
1732 IF U(J9,1)>0.0 THEN 1745
1733 IF U(J9,1)<0.0 THEN 1745
1735 LET A(I8,J9)=0.0
1740 GOTO 1750
1745 LET A(I8,J9)=1.0/U(J9,1)
1750 NEXT J9
1755 NEXT I8
1757 LET I4=INT(I4)
1760 LET B(I4)=A(1,1)
1765 LET J2=I4-1
1767 SETW :5 TO 1
1770 FOR I9=1 TO K STEP 1
1775 LET J2=J2+1
1785 READ :5,O(1),O(2),O(3),O(4),O(5),O(6)
1790 FOR J9=1 TO 6 STEP 1
1795 LET L2=6*(J2-1)+J9
1800 LET C(I4,L2)=O(J9)
1805 NEXT J9
1810 NEXT I9
1815 IF N4<>2 THEN 1830
1820 IF N5<>1 THEN 1830
1825 GOTO 1835
1830 GOTO 1900
1835 LET N(1)=H1
1840 LET P(1)=J1
1845 LET X(1)=X1
1850 LET Y(1)=X2
1855 LET Z=X3
1860 LET A4=X4
1865 LET B1=X5
1870 LET A4=X6
1875 LET A6=X7
1880 LET D1=X8
1885 LET D2=X9
1890 LET F(1)=U1
1895 LET A3=U2
1900 IF N5-K6>=0 THEN 1925
1905 GOTO 1510
1910 REM -------------------------------------------------------------------
1915 REM END OF DO LOOP
1920 REM -------------------------------------------------------------------
1925 LET K=K6
1930 IF N4-1<>0 THEN 1955
1935 GOTO 1940
1940 FOR I9=1 TO K STEP 1
1945 LET X(I9)=S6*(I9-1)
1950 NEXT I9
```

```
1955 FOR I9=1 TO K STEP 1
1960 LET K4=K-I9+1
1965 LET J2=I9
1970 NEXT I9
1975 ON N4 GOTO 1980,1990,2000
1980 LET P2=B4*A5/(F(1)*B5)*K
1985 GOTO 2010
1990 LET P2=B4*A5/(F(1)*B5)+B4*A5/(F(2)*B5)*(1/SIN(ATN(1/N(2))))
1995 GOTO 2010
2000 REM LET P2=0.0
2001 REM FOR I9=1 TO K STEP 1
2002 REM IF N(I9)=0.0 THEN 2005
2003 REM LET P2=P2+B4*A5/(F(I9)*B5)*(1/SIN(ATN(1/N(I9))))
2004 REM GOTO 2006
2005 REM LET P2=P2+B4*A5/(F(I9)*B5)
2006 REM NEXT I9
2007 LET P2=10000
2010 LET N6=N4
2012 DISP USING 2013,P2
2013 :PMAX= ####.####↑↑↑↑
2015 GOTO 2085
2020 REM ----------------------------------------    ---------
2025 REM PRINT SUBROUTINES
2030 REM ----------------------------------------
2035 FOR I9=1 TO 2 STEP 1
2040 PRINT
2045 NEXT I9
2050 RETURN
2055 FOR I9=1 TO 4 STEP 1
2060 PRINT
2065 NEXT I9
2070 RETURN
2075 REM ----------------------------------------
2080 REM WRITE DATA INTO FILES
2085 REM ----------------------------------------
2090 LET U1=0
2095 SETW :1 TO 1
2100 SETW :2 TO 1
2105 SETW :4 TO 1
2110 MAT WRITE :2,M,Q,V,H,U,G,L,S
2115 WRITE :2,J6,I3,N1,N2,K5,K3,N3,E1,G3,A1
2120 WRITE :2,A3,A6,D1,D2,A5,B1,A4,K,Z,U1,K8,B5,B4,C7
2121 FOR I9=1 TO K8 STEP 1
2122 WRITE :2,F(I9)
2123 NEXT I9
2125 FOR I9=1 TO K8 STEP 1
2130 WRITE :2,X(I9),Y(I9),N(I9),P(I9)
2135 NEXT I9
2140 MAT WRITE :4,C
2145 FOR I9=1 TO 10 STEP 1
2150 WRITE :4,B(I9)
2155 NEXT I9
2159 WRITE :4,N5,K6,I4
2160 IF N4<>2 THEN 2172
2165 IF N5<>1 THEN 2172
2170 WRITE :4,P1,T1,H1,J1,X1,X2,X3,X4,X5,X6,X7,X8,X9,W1,W2
2172 WRITE :1,A1,G3,E1,N4,N3,U2,J6
2175 ON N4 GOTO 2180,2184,2194
2180 WRITE :1,K,S6,Z1,Z2,Z3,Z4,Z5,Z6,Z7,Z8,Z9,Y1,Y2,K8
2182 GOTO 2300
2184 WRITE :1,H2,A3,D1,D2,A5,B1,A4,A6,B4,B5,C7
```

```
2186 FOR I9=1 TO 2 STEP 1
2188 WRITE :1,F(I9)
2190 NEXT I9
2192 GOTO 2300
2194 WRITE :1,K,N3,N1,N2,K5,K3,K8
2196 FOR I9=1 TO K8 STEP 1
2198 WRITE :1,N(I9),P(I9),X(I9),Y(I9),Z,F(I9),A3
2200 NEXT I9
2202 WRITE :1,A4,A5,B1,A6,D1,D2,B4,B5,C7
2203 WRITE :1,Q(1,1),Q(2,1),Q(3,1),Q(4,1),Q(5,1),Q(6,1)
2204 IF N3=0 THEN 2300
2206 FOR I9=1 TO N3 STEP 1
2208 WRITE :1,M(I9,1),M(I9,2),M(I9,3)
2210 NEXT I9
2300 SETW :6 TO 1
2305 WRITE :6,B(1)
2320 SETW :7 TO 5
2335 WRITE :7,K,B1
2337 IF U2=1 THEN 2512
2340 SETW :8 TO 1
2345 WRITE :8,P2,F(1)
2350 SETW :9 TO 1
2355 WRITE :9,E1
2395 SETW :10 TO 1
2400 WRITE :10,P2,A6,A5,C7,B5,K
2401 FOR I9=1 TO K STEP 1
2402 WRITE :10,F(I9)
2403 NEXT I9
2405 FOR I9=1 TO 10 STEP 1
2410 FOR J9=1 TO 60 STEP 1
2415 WRITE :10,C(I9,J9)
2420 NEXT J9
2425 NEXT I9
2430 SETW :11 TO 2
2435 WRITE :11,N6
2500 REM ------------------------------------------------------
2505 REM CHAIN STATEMENTS
2510 REM ------------------------------------------------------
2512 IF U2=1 THEN 2520
2515 CHAIN "*MAINL1"
2517 GOTO 3000
2520 CHAIN "*S3363"
3000 END

END OF LISTING
```

END

DATE
FILMED

6-81

DTIC